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Reprinted from the AMERICAN JOURNAL OF PSYCHOLOGY,  
Vol. XII, July, 1901, pp. 409-457;  
Vol. XIII, April, 1902, pp. 219-268.



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AN ANALYTIC STUDY OF THE MEMORY IMAGE  
AND THE PROCESS OF JUDGMENT IN THE  
DISCRIMINATION OF CLANGS  
AND TONES.

By

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Thesis presented to the University Faculty of Cornell University for the  
Degree of Doctor of Philosophy.

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## AN ANALYTIC STUDY OF THE MEMORY IMAGE AND THE PROCESS OF JUDGMENT IN THE DISCRIMINATION OF CLANGS AND TONES.

By GUY MONTROSE WHIPPLE, A. B., Ph. D., Assistant in Psychology  
at Cornell University.

### INTRODUCTORY.

During the winter of 1897-98, the writer, then a student at Clark University, was attracted to the problem with which the present investigation deals by the observation of several rather unusual instances of 'pitch memory.' These observations led to an experimental investigation which was instituted with a view of analyzing qualitatively the structure of such processes of discrimination. The tests were, however, of an unsystematic nature, and were mainly restricted to personal observations conducted with the aid of a piano.

The more detailed and systematic study of the problem, the results of which are embodied in the present paper, was undertaken in the Psychological Laboratory at Cornell University during the academic years 1898-99 and 1899-1900. An added interest was given to the problem, and a favorable setting secured for the necessary experimentation, by the fact that there had just been completed in the same laboratory an essentially similar study in the domain of vision.<sup>1</sup>

Since this article fully discusses the general bearing of the problem in hand, the present paper needs but little introduction. It may be well, however, to recount briefly the features of the preceding work which bear especially upon the prob-

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<sup>1</sup> I. M. Bentley: The Memory Image and its Qualitative Fidelity, this *Journal*, XI, 1899, 1-48.

lem, and also to make preliminary mention in this place of certain previous publications upon pitch memory which must necessarily be handled in some detail in the discussion of our results.

Setting out from Kuelpe's contention that much of the work on memory has assumed without sufficient cause the presence of a memory image, and that the term has been too loosely applied, Bentley has given a review of the literature bearing upon the memory image and the methods of its investigation, has discussed its genesis and function, and conducted an experimental study of the qualitative fidelity of memory images of color and brightness. He points out that the modern laboratory researches in this field have been chiefly pedagogic and popular rather than analytic in nature.<sup>1</sup>

The chief methods for the study of the image are those of reproduction, recognition, comparison, and description. In view of the schematic nature of the reproduced elements, an important analytic problem is afforded if we seek to determine not how much of a given impression can be reproduced, but what is the nature of the centrally excited processes which form the basis of the act of reproduction or of recognition.

Both Wolfe<sup>2</sup> and Lehmann<sup>3</sup> assumed the presence of a memory image in the recognitory consciousness; Hoeffding<sup>4</sup> posited an unanalyzable 'quality of knownness' which had its physical substrate in a certain ease of molecular movement in the cortex; Washburn<sup>5</sup> has advanced the hypothesis that recognition is a peculiar property of centrally excited sensations, possibly mediated by the excitation of connective brain tracts; Kuelpe<sup>6</sup> has mentioned effectiveness for the arousal of centrally excited sensations *plus* a mood of familiarity; Baldwin<sup>7</sup> the ease of motor adjustments of attention; and Wundt<sup>8</sup> a feeling of recognition supported by a background of ideas.

Perception, like recognition, does not necessarily include reproduction, although it involves the past experience of the individual. We may arrange a schema of types of meaning-consciousnesses which shall show at a glance the part played by the image. Such a schema is given herewith:

1. Cognition (perception): no image introspectively discoverable.

<sup>1</sup> The articles of Philippe, *Rev. phil.*, Vol. XLIII, 1897, 481-493, *ibid.*, Vol. XLIV, 1897, 508-524, by their emphasis of the analytic study of the image for its own sake, form a pleasing exception to this tendency.

<sup>2</sup> *Phil. Stud.*, III, 1886, 556-558.

<sup>3</sup> *Phil. Stud.*, V, 1889, 118-119.

<sup>4</sup> *Vierteljahrsschrift*, 1899-90.

<sup>5</sup> *Phil. Rev.*, VI, 1897, 267.

<sup>6</sup> *Outlines of Psychology*, 1895, p. 172.

<sup>7</sup> *Mental Development*, 1895, 313 ff.

<sup>8</sup> *Phil. Stud.*, VII, 1892, 344 ff.

## 2. Recognition.

- A. Direct recognition : no image is necessary (whether the process be conducted with active or passive attention) save in the form of direct recall (memory in the narrow sense).
- B. Mediate recognition : when it involves conscious comparison an image is implied, but otherwise auxiliary ideas or other motives may be sufficient.

Bentley's experimental tests were conducted mainly by the method of recognition, with special precaution to secure knowledge of the presence or absence of the image just at the end of the time-interval. In the first series, conducted with open eyes, the observers did not try to hold the brightness image. Images were present in five-sixths of the tests. They could be recalled better at the end of five minutes than at the end of one minute. On the other hand, there were frequent instances of flash-like, absolutely certain judgments, where there is no trace of comparison and no vestige of an image,—judgments in which "the work seems to have all been done for consciousness."<sup>1</sup> There was a constant tendency toward lightening of the imaged brightness. The second series proceeded by a continuous change method. The results showed that the method hindered the employment of the image in processes of comparison, and that the individual variations were large. Although the standard was approached from two directions, yet a large amount of expectation might obscure any constant memory error. The quantitative results exhibited large mean variations.<sup>2</sup>

The third series reported by Bentley was made by the method of right and wrong cases, with special regard to the stimulation of the retina during the interval (2-60 secs.). In these tests the observer was asked to hold the image actively. The result of non-stimulation of the retina during the interval was to darken the brightness image. The amount of darkening and consequent loss of accuracy increased slowly from 2 to 60 seconds, but without the peculiar periodicity asserted by Wolfe and others.

In conclusion Dr. Bentley adds: "Simple recognition stands much nearer positive or negative identification (expressed by affirmative or negative judgments) than it does to pure memory, and the alleged act of comparison with a memory image is rather a logical formulation, suggested by the judgments 'like' and 'different,' than a psychological statement of fact. Where the image is available memory is slightly more accurate," but recognition may be sure and precise when the image plays no part.

The experiments of Wolfe<sup>3</sup> by the method of right and wrong cases

<sup>1</sup> Chronoscopic measurements of such immediate judgments, in the case of recognition of tones, will be given later.

<sup>2</sup> A detailed discussion of the application of this method to the problem in audition will be given later.

<sup>3</sup> *Phil. Stud.*, III, 1886, 534-571.

are, as regards the materials (clangs of the Appunn tonometer) and the intervals employed (mainly 2 to 60 seconds), more in accord with those of the present investigation than the experiments upon the fidelity of the visual memory image just reviewed, although in their essential purpose, since they were concerned with a functional investigation (the capacity for tonal recognition as conditioned by time interval), they are not at all closely allied to our experiments. More especially, Wolfe, as has already been mentioned, assumed that the quotient  $r/n$  (method of right and wrong cases) measured the fidelity of the memory image. This assumption depends in turn upon the hypothesis that the image is always actively present in the judgment. Thus he says (p. 556): "Gehen wir naehler auf das Verfahren beim Vergleichen zweier durch einen Zeitraum getrennten Toene ein, so ist klar, dass ohne ein Erinnerungsbild des ersten Tons eine Vergleichung ueberhaupt unmöglich ist. Dieses Erinnerungsbild ist gewissermassen der Massstab, an welchem der zweite oder Vergleichston gemessen wird." This quotation should be qualified by the following (p. 558): "Es ist aber bekanntlich nicht noetig ein bleibendes Bild im Bewusstsein zu behalten, um eine Vergleichung zu vollziehen. Selbst wenn keine bewusste Spur des ersten Tones zurueckbleibt, ist ein Urtheil oft möglich, indem der zweite Ton sofort ein Bild des ersten hervorruft."

The tone differences employed by Wolfe were 4, 8, and 12 vibrations;<sup>1</sup> the categories of judgment were 'same,' 'different' (higher or lower) and 'doubtful.' The results of the series with 4 vibs. D showed that there were more right cases with  $D=0$  than with  $D=\pm 4$  vibs. The series with 8 vibs. showed that the comparison of different tones ( $D=\pm 8$ ) was less influenced by time-interval than was the recognition of the same tone as 'same' ( $D=0$ ). In the series with 12 vibs. there were still instances, even at four seconds interval, in which difference was recognized, but not the direction of the difference.

The discussion of the dependence of the results upon time-interval brings out the following statements. Despite many disturbing individual factors, more especially that of practice, it may be said that, in general, fidelity of the memory image for pitch decreases in such a manner that the time-interval must increase approximately in geometrical progression in order to effect equal amounts of decrease of retentiveness.<sup>2</sup> The optimal time for judgment is at 2 secs. At between 10 and 20 seconds (depending upon the observer) there is a rise in the number of right cases which may indicate, according to Wolfe, not only a cessation of the disintegration, but a positive renewal of the image. Whether the explanation be in terms of large periodic variations of apperception (attention to the image) or of the influence of

<sup>1</sup> In every case  $D=0$  was included.

<sup>2</sup> This law is based upon the results for  $D=0$ .

tonal after-images,<sup>1</sup> the periodicity, as evinced by the curve of right cases, remains an assured fact. The phases of clearness in the image may be assumed to be approximately constant for the same individual and the same degree of effort. The periodicity, therefore, points to a like periodicity in the attention, since clearness of memory is assumed to be dependent upon the attention.

Other general results are that  $D=0$  is oftener judged higher than lower; higher is oftener judged correctly than is lower, and lower is oftener judged higher than higher is judged lower. These results are due to the fact that there is a tendency to estimate the memory image owing to its lessened intensity, as lower than an actually heard tone of the same pitch. Practice effects are prominent in the early stages especially in the case of unmusical subjects. Such practice effects seem to be rather restricted in their application; thus Wolfe, who was unmusical, became able to discriminate higher from lower with considerable exactness with a  $D=4$  or 8 vibs., but curiously enough was then far less certain with a  $D$  of 30 or 40 vibs.

Our general criticism of the work of Wolfe can be well emphasized at this point by a quotation from the recent monograph by Martin and Mueller.<sup>2</sup> It is a source of satisfaction to find that these authors, whose general purpose, as indicated by the title of their work, is identical with our own, have made express mention of the desirability of investigations along lines which our experiments have attempted in part to cover. After referring to the experimental setting of Wolfe's work they say (pp. 230-1): "Man hat nun die Ansicht ausgesprochen, dass die Resultate derartiger Versuche ohne Weiteres geeignet seien, uns Auskunft darueber zu geben, wie die Treue der Erinnerung an den Normalton (oder sonstigen Normalreiz) im Verlaufe der Zeit abnimmt. Diese Behauptung laesst die erforderliche Vorsicht des Denkens vermissen. Aus Resultaten von Versuchen der soeben erwähnten Art kann man betreffs des Ganges, den die Treue der Erinnerung im Verlaufe der Zeit nimmt, offenbar nur dann etwas erschliessen, wenn man zuvor in wissenschaftlicher Weise etwas Sichereres ueber die Beziehung ausgemacht hat, in welcher die Resultate derartiger Versuche zu der Treue der Erinnerung stehen, also zuvor den Vorgang, welcher bei Vergleichung eines Sinneseindruckes mit einem vorausgegangenen Sinneseindrucke stattfindet, nach allen wesentlichen Seiten hin sicher aufgeklaert hat. Zur Zeit liegt aber ein ernstlicher Versuch, eine Aufklaerung ueber das Wesen dieses Vorganges zu erlangen, . . . ueberhaupt nicht vor."

While it is scarcely desirable to recount the experiments of Martin and Mueller, because of the disparity between their materials (lifted weights) and tones,—a disparity which is accentuated by the introduc-

<sup>1</sup> "Eine periodische Tendenz zur Erneuerung einer Tonempfindung eine Zeit lang nach dem Aufhoeren des Reizes fortexistiert" (p. 557).

<sup>2</sup> Zur Analyse der Unterschiedsempfindlichkeit, Leipzig, 1899.

tion of an important and complicated factor, that of active movement upon the part of the observer,<sup>1</sup>—yet it seems fitting to make specific reference here to this monograph as a noteworthy contribution to the analytic study of the judgment process. This emphasis of analysis as the ultimate problem of the psychologist is well expressed upon page 225: "Man wird mit uns darueber uebereinstimmen, dass fuer die Psychologie nicht die Untersuchung jener irgendwie definirten Unterschiedsempfindlichkeit die letzte Aufgabe ist, sondern die Untersuchung der Factoren, auf deren Wirksamkeit die Urtheile ueber die zu vergleichenden Sinneseindruecke und die Besonderheiten dieser Urtheile beruhen. Jeder jener Factoren ist, so weit es eben geht, hinsichtlich seiner Natur und Wirkungsweise und hinsichtlich seiner Abhaengigkeit von den Versuchsumstaenden zu untersuchen." Such of the detailed results of this monograph as are applicable to the sphere of audition will be discussed later.

In an article upon the "Experimental Investigation of Memory,"<sup>2</sup> Kennedy has entered a plea for the analytic study of the memory image. Thus he says (p. 484): "The general problem of memory, as it is now conceived, is that of tracing the transformations which take place in each content as it passes through time." But it is evident that Kennedy still holds to the necessity of an image in the judgment process. We quote from page 485. "In order that a certain object be remembered it is necessary . . . that some image of it be retained after it has gone." The words "some image of it" leave, perhaps, room for misinterpretation: still this author has apparently not considered it possible for a content to be recognized without the use of a memory image; nor, what is more, has he considered it possible for elementary contents, such as tones, to be recognized without the aid of a memory image of their own kind. This criticism is, I think, justified by a statement on p. 482, when, after having distinguished 'immediate' from 'mediate' (conceptual) memory, he says: "If what we are to remember is some delicate shading of color or some fine variation of pitch, it must be recollected immediately." Bentley's experiments with finely graded visual qualities<sup>3</sup> and our own with finely graded tonal qualities show that recognitory judgments in which there is no memory image of the original stimulus are not only possible but frequent. This same objection to Kennedy's treatment arises as one reads his discussion of the fading of the image (p. 492). He urges that, until possible qualitative and quantitative (intensive, temporal, spatial) variations of the image are excluded, we

<sup>1</sup> The disparity extends also to many of the detailed conditions of experimentation. For example, our use of a number of irregularly placed standard stimuli makes a distinct difference between our tests and those of Martin and Mueller. Thus there is no evidence in our experiments of anything analogous to the judgments passed absolutely upon an isolated weight.

<sup>2</sup> *Psych. Rev.*, V, 1898, 477-499.

<sup>3</sup> See especially pp. 39-40.

cannot be sure that  $r/n$  measures this fading. We prefer to say that  $r/n$  does not necessarily tell us anything at all about the condition of the image.

In view of this criticism, we fail to see how any amount of tables can furnish data for the plotting of curves of qualitative or quantitative change in the image. The only reliable guide to the transformation of the memory image in time is the careful introspection of the observer himself.<sup>1</sup>

There remain to be mentioned the experiments of Angell and Harwood,<sup>2</sup> which are essentially similar to ours in Part I. They involve a study of the discrimination of tonometer clangs (512-1024 vibs.) under varying conditions of time-interval (1-60 secs.) with reference to the presence and function of the memory image. One-half of the judgments, however, are obtained under conditions of distraction. In their summary of results Angell and Harwood assert that "no law can be laid down in regard to a decrease in accuracy of the so-called tone-memory for intervals up to 60 seconds; the most that can be said is that there is a small and irregular falling off for some [observers] and no falling off for others." On the other hand, there is a very marked falling off in accuracy of judgment with increase of time interval for  $D=0$ . This latter finding is, of course, in agreement with Wolfe.

In the second paper (p. 58) Angell discusses the results gained by the use of various distractors: adding, counting metronome beats, reading backwards, listening, and clang discrimination. Their outcome may be gleaned from the following quotation: "The main conclusion to be drawn from the distraction experiments is that judgments of tone discrimination can take place, and in the majority of our experiments did take place, without conscious comparison between the present sensation and a memory image of a past sensation."

One can but regret that Angell did not pay more attention to the introspective evidence. The excuse offered, viz., that too much stress upon the introspection would have invalidated the quantitative results, seems to us to be negatived by the evidence of our own experiments. In the short intervals one can formulate the introspective report entirely by 'post mortem' examination. In the longer intervals the introspection formulates itself in verbal phrases as the test proceeds. Only rarely does this process distract from the decision at the end of the interval. The cases reported read something like this: "Image fluctuated with my breathing. Got thinking about this and lost it." As was natural, this sort of self-consciousness about the experiment occurred most often in the writer's own observations. That it is not a prominent source of error may therefore be inferred from the fact that his right cases exceed in number those of any of the other observers.

<sup>1</sup> For further discussion of these and cognate points in Kennedy's article, see Bentley, *op. cit.*, p. 13.

<sup>2</sup> This *Journal*, XI, Oct., 1898, 67; *ibid.*, XII, Oct., 1900, 58.

## CHAPTER I.

## EXPERIMENTAL.

The following experiments were conducted in the acoustic room<sup>1</sup> of the Cornell laboratory.

For convenience in discussion and tabulation the course of experimentation is divided into two parts, the second of which is further subdivided into four series. Each section will be treated in general as a distinct line of investigation.

## PART I.

The experiments comprised under Part I are in a certain sense a repetition of one of the series published by Wolfe in 1886,<sup>2</sup> but, as we have already pointed out, our purpose is quite different; we wish to trace introspectively the nature and course of the tonal memory image,<sup>3</sup> and to analyze the processes of judgment. For this reason our experiments are fewer in number for each observer, but especial emphasis is laid upon each individual test.

*Instrument.* All the tones in Part I are given by an Appunn tonometer (512-1,024 vibrations) actuated by the Appunn bellows. A weight of 4.7 kg. upon the main bellows and a weight of 1 kg. upon the lid of the tonometer give satisfactory duration and intensity.<sup>4</sup> On the other hand we have found it very difficult to obtain a sufficient number of series of tones of similar clang tint.<sup>5</sup> The tones finally chosen as standards are 612, 724, 832, 928 and 984 vibrations, denominated *a*, *b*, *c*, *d* and *e* respectively. The difference (D) amounts to 0 or to  $\pm 8$  vibs., so that, besides the standards, there are used the reeds giving 604, 620, 716, 732, 824, 840, 920, 928, 976, and 984 vibrations.

The choice of these tones must be made by laborious testing of the whole tonometer. It is obviously important that at least within a given group ( $N$ ,  $N+8$ ,  $N-8$ )

<sup>1</sup> This room is not intended to be sound-proof, but it offers distinct advantages for the prosecution of such studies as the present, in view of (1) its isolation by heavy walls from the other parts of the laboratory, (2) its length, which enabled the observers to sit 9 meters from the instrument, where they were not distracted by the noise incident to its manipulation, (3) the adjustable hanging curtains for the elimination of echoes, and (4) the complete electrical connections with other rooms, more especially with the 'registration room,' which enabled chronometric readings to be taken without disturbance to the observers. Practically the only distraction to the experiment came from sounds external to the building. Whenever such distractions were reported the test was thrown out.

<sup>2</sup> *Op. cit.*, especially p. 542.

<sup>3</sup> We include both the memory image proper and the memory after-image. See Fechner, *Elemente der Psychophysik*, Leipzig, 1889, 2nd ed., II, 468 ff., and Bentley, *op. cit.*, p. 15.

<sup>4</sup> More especially as it is thus unnecessary to operate the bellows during the clang. A single downward thrust of the foot is made simultaneously with the 'ready' signal. This suffices to produce a steady tone of one second's duration beginning two seconds after the signal.

<sup>5</sup> Cf. Stumpf and Meyer, *Zeits. f. Psych.*, XVIII, 1898, 330.

the qualitative variation of the stimulus shall predominate, and that the 'color' variation shall be minimal; otherwise there may result a judgment based upon the difference of color and not upon a true qualitative discrimination.

While the groups selected are of uniform color, they do not all furnish exactly the D (8 vibes.) desired.<sup>1</sup> We prefer, however, to use these reeds, since their color is uniform and their deviation from the desired D can be computed and properly distributed in the evaluation of the results.

The computation of the actual differences, *plus* and *minus*, from the five standard tones of the instrument was effected by counting the beats between the standard and the next reed above or below (*i. e.*, 4 vibes.), and then the beats between the latter and the reed supposed to give the D required (8 vibes.). In every case we made four counts of the beats, grouping by fours, and with a stop-watch took the time consumed by 56 beats. In order to avoid the irregularities of intensity which would ensue were one to actuate the reeds by the bellows for so long a time (circa 14 secs.), we applied to the tonometer a compressed air device which furnished a steady and adequate air supply at the proper pressure for over 20 seconds. The results obtained by this method showed the actual D's to be as follows:

D for <i>a</i> +,	7.678	vibs.
D " <i>a</i> -,	7.771	"
D " <i>b</i> +,	8.000	"
D " <i>b</i> -,	6.815	"
D " <i>c</i> +,	8.415	"
D " <i>c</i> -,	8.664	"
D " <i>d</i> +,	8.271	"
D " <i>d</i> -,	8.456	"
D " <i>e</i> +,	10.212	"
D " <i>e</i> -,	7.875	"

Average,  $8.215 \pm .587$  vibes.

Inspection of this list shows that the average D used is 8.215 vibes.; the mean variation, 0.587 vibes.; the average *plus* D is 8.515 vibes.; the average *minus* D, 7.916 vibes. The influence of each particular D on the results will be mentioned later, when the influence of absolute pitch is discussed.

*Method of Procedure and General Arrangement of Tests in Part I.* During a large part of the experimentation we have found it both economical and entirely feasible to work with three observers at each sitting of one hour weekly. The observers are isolated from one another by large cardboard screens, and provided with prepared blanks upon which they record at the end of each test, their judgment, -equal (=), plus (+), minus (-), or doubtful (?);<sup>2</sup> -their certainty, and detailed introspection as to the course of the image and the process of judgment.

The experimenter gives the usual 'ready' signal two seconds before the first or standard stimulus (N).

For the determination of the length of the intervals and of the tones there is fastened to the framework of the bellows immediately behind the tonometer, an upright provided with a horizontal arm from which hangs a simple pendulum. This pendulum consists merely of a thread and lead bob so adjusted as to swing in seconds. We prefer, for various reasons, a silent metronome of this sort to the ticking metronome employed by Wolfe.

<sup>1</sup> Stumpf and Meyer, *loc. cit.* p. 327.

<sup>2</sup> In the second half of the experimentation, doubtful tests are repeated until the observer makes satisfactory judgment, but the number and distribution of these cases are recorded.

After waiting for an interval of 2, 4, 6, 10, 15, 20, 30, 40, or 60 seconds, the experimenter gives the variable or comparison stimulus (V), which is either the same as N ( $D=0$ ), or higher ( $D=+8$ ), or lower ( $D=-8$ ). No ready signal is given before V, even in the long intervals. The reasons for this are: first, that the *speaking* of a 'ready' or 'now' at the end of the interval, when the subject is attending 'with might and main' to the memory image, proves to be a distraction rather than a help; while, secondly, the slight but unavoidable noise of pumping the bellows for V, which the experimenter soon comes to produce quite uniformly and at a constant time before V, affords an entirely adequate and yet unobtrusive signal for the attention of the subject to the second tone. Both stimuli last one second, as nearly as the operator can manipulate the stops in time to the swing of the silent metronome.

The further arrangements of the tests of Part I may be summarized as follows. In each hour of experimenting, each observer is given each one of the standard tones, *a*, *b*, *c*, *d*, *e*, three times; once followed by  $V=N$ , once by  $V=N+8$  vib., once by  $V=N-8$  vib. The order is, of course, quite irregular, though the same for each observer in a given test, and care is taken that the same N is never given twice in succession; for our preliminary tests show that many observers, even after spending two or three minutes in writing their introspection, are able to identify a repeated N as identical with that of the preceding test.<sup>1</sup>

Several weeks were given to preliminary determinations<sup>2</sup> both for the sake of practicing the observers and in order to settle upon favorable detailed conditions of procedure. After this practice period, to the results of which we shall make incidental reference, the experiments proper of Part I began.

Part I is practically subdivided in point of time into a first and a second half. In the first half the intervals (time elapsing between N and V) are taken up in the order 2, 60, 4, 40, 6, 30, 10, 20, 15; in the second half exactly the reverse order is maintained. The object of this arrangement is to distribute as evenly as possible whatever practice effects might persist after the termination of the preliminary period especially designed to familiarize the observers with the work. The results later to be discussed show that the practice curve does gradually rise during at least the first half of Part I.

It is obvious that the number of tests for each interval is

<sup>1</sup> The extent to which the constant use of one or a very few standards may affect the observer's judgments is well exhibited in the analyses of Martin and Müller, *op. cit.*, 43 ff.

<sup>2</sup> These include tests with 4 and 8 vib. D at 10 and 20 secs. interval, and tests of distractors, especially reading.

doubled by the arrangement just mentioned. Accordingly each of the six observers passes  $15 \times 2$ , 30 judgments upon each one of the nine intervals, so that the total number of tests represented in Part I, for all subjects and all intervals, is 1,620. The number of cases for each time-interval, 180, is relatively small as compared with the enormous number of tests which many investigators have employed when working by the method of right and wrong cases, but we do not wish to place any high degree of insistence upon the generalizations which we shall base upon purely quantitative results, since our immediate purpose is analytic. We are interested rather in the structure of the conscious processes which run their course during the time-interval and during the formation and expression, whether by word of mouth or reaction movement, of the judgment which terminates each test. We insist that, from this point of view, mere numbers are not an essential to the legitimate conduct of the psychological experiment; on the contrary, given the proper, the optimal conditions (of practice, attention, etc.), each test which includes the careful introspection of a trained observer has a right to demand for itself a hearing, to be regarded as a datum. Every such test counts for one experiment.

*Subjects.* The subjects in the experiments of Part I are all students in Cornell University who have had training both in general psychology and in the introspection of laboratory drill work. Since the investigation of any such problem in acoustics as the one here presented must take into account, in a rather detailed manner, the musical training of the persons concerned, it seems too vague to classify the subjects roughly as 'musical' or 'unmusical'; hence there follows a brief 'musical history' of the six subjects who participated in Part I.

1. *M.* (Miss M. F. McClure), a few piano lessons; has studied harmony; a slight acquaintance with the banjo and mandolin; sings alto or low soprano parts; carries airs very easily; generally fond of music, especially of church-organ or orchestral effects, which often incite brilliant photisms.<sup>1</sup> Introspection painstaking and detailed, but liable to be influenced at times by suggestion. Generally alert mentally.

2. *W.* (Mr. J. H. Wilson). Non-musical family; no lessons in singing or upon any musical instrument; very fond of music; prefers piano to any single instrument, the orchestra to the brass band; whistles and hums popular airs a great deal. Despite certain of these indications *W* must be classed as strictly unmusical, as will be shown by many features of his introspection. Unfortunately his absence during the second year of experimentation forestalled a series of subsidiary tests which had been planned to elucidate some of his peculiarities. Tendency to retain N by aid of articulation.<sup>2</sup> Very slow and cautious in judgment; of a distinctly phlegmatic type.

<sup>1</sup> For a detailed account of the photisms and allied phenomena of *M*, see this *Journal*, X, 1900, 318.

<sup>2</sup> Actual articulation or humming was, of course, excluded.

3. *S.* (Miss Claire Seymour). Unmusical, as were her parents; piano lessons when from 12 to 15 years old, including moderately difficult selections, but these were invariably acquired by committing to memory the appropriate keys; cannot recall at will more than a dozen notes of any selection however many times it has been heard. One term singing lessons; sings soprano, but only when in a loud chorus and 'carried along' by the others. Very fond of music; prefers church organ, orchestra, and male voices. Strong liking for all low tones on account of their fullness and cool soothing character. When a child, emotional, thrilling music,—especially that in which low tones predominated,—aroused photisms which formed quite an important mental feature for about two years. Early in the course of these experiments *S* developed visualizations which came to be uniformly present, and which at times served as a basis for judgment. These will be discussed later. *S*, as above mentioned, also associated temperatures with tones. High tones were warm and unpleasant, low tones cool and pleasant (like the bathing of hands and face in cool water). Tests of *S*'s photisms revealed nothing worthy of detailed mention. Introspection good, though occasionally restricted by a spirit of competition; *S* worried to think other observers might be getting more right cases.

4. *F.* (Mr. H. H. Foster). Distinctly musical. Training: the usual vocal instruction in public schools supplemented by about six years private lessons. Voice, bass (*E* to *e'*); uses solmization. Occasional obsessions of 'tunes in the head.' Plays violin often, piano less often. Strong tendency to fix the pitch of *N* by humming. Introspection quite good, but of a general sort, lacking finer details; constitutionally tired.

5. *L.* (Mr. E. T. Lies). Mother musical; father fond of music, but not a musician. *L* took piano and organ lessons for eight years; early taught to sing; has done a large amount of singing in choirs and choruses, for a time being organist and chorister. Voice baritone (*G* to *d'*). Cannot commit to memory easily; prefers orchestral music in general, and always harmonic music to solos of any sort. Frequent obsessions of 'tunes in the head,' mostly instrumental music; a single selection is apt to prevail for one or two days. Introspection rather scanty, stereotyped, and subject to logical bias, *e.g.*, that judgment was impossible without conscious comparison.

6. *Wh.* (the writer).<sup>1</sup> Distinctly musical; plays piano, banjo, mandolin and guitar; sings baritone; has had vocal instruction. Auditory imagery generally prominent; centrally excited tonal imagery, both vocal and instrumental, melodic and harmonic, very prevalent, especially when incited by any sort of rhythmic action, such as walking or eating. The presence of so much auditory imagery is, as might be expected, the correlate of a well developed capacity to reproduce all sorts of music at will. From continual service as experimenter as well as observer, *Wh* naturally obtained a very high degree of practice. There is no vestige of memory for absolute pitch.

(To translate this classification of the subjects for comparison with the German standards, we should say that *W* and *S* are hopelessly 'unmusikalisch'; *M* is also strictly speaking 'unmusikalisch,' though possibly ranking as 'wenig musikalisch.' *L*, *F*, and *Wh* would be 'musikalisch' in any German monograph, but they have perhaps none of them been favored with so many opportunities to listen to good music as would be implied by the connotation of the German adjective.)

*Results of Part I.* It follows, both from the general object and nature of these researches, as well as from the wide variation of the capacities of the observers to image tones, that the general crude results of the experiments are of relatively less importance than the more distinctly analytic data which we shall present for the most part under the heading "dependence upon the individual." Yet the individual variations must be

<sup>1</sup> Our thanks are due to Mr. W. B. Secor for serving as operator for *Wh.* during Part I, and to Dr. W. C. Bagley for a similar service in Part II.

discussed in the light of the general and average results, and, moreover, despite the smaller number of cases, we believe that the numerical results are worthy of consideration as regards their relation to the Tables obtained under similar conditions by Wolfe and by Angell and Harwood.

TABLE I.\* (1620 tests.)

Inter- val	D = 0			D = + 8			D = - 8			Doubt- ful.	Total right cases.
	r	+	-	r	=	-	r	=	+		
2	51	6	3	39	8	13	40	8	12	0	130
4	48	6	6	43	10	7	35	15	9	1	126
6	45	6	9	42	9	9	32	20	8	0	119
10	45	7	8	39	10	10	38	17	5	1	122
15	49	6	5	42	6	12	37	14	9	0	128
20	40	14	6	38	14	8	31	17	11	1	109
30	30	20	10	37	14	9	34	18	8	0	101
40	34	9	16	31	20	8	40	11	9	2	105
60	29	12	19	32	12	14	36	14	8	4	97
Total,	371	86	82	343	103	90	323	134	79	9	1037

\* r denotes the number of right cases, + the judgment 'higher,' - the judgment 'lower,' and = the judgment 'equal.' The nine doubtful cases are, for convenience, given in a single column. For their distribution, see below.

Table I gives the distribution of the judgments of all six observers for the tests of Part I. Attention is called to the following numerical features:

i. *The right cases:*

(a) *Increase of time-interval causes a general decrease in the total number of right cases. At two points, however (15 and 40 seconds), the curve is peaked.*

(b) *Both the general decrease and the two points of resurgence in the total number of right cases are traceable practically to the results for D=0 alone.*

(c) *Increase of time-interval effects a very slight but fairly uniform decrease in the right cases for D=+8.*

(d) *Increase of time-interval has practically no effect upon the number of right cases for D=-8.*

The fact that the cases for D=0 suffer most as time elapses is in accord with the results both of Wolfe and of Angell and Harwood. The rise in this curve at 15 and 40 seconds appears to corroborate strongly Wolfe's contention for a periodic renewal of the tonal memory image. We shall see how further analysis of the results bears out this hypothesis.

(e) *The total number of right cases is greatest for D=0, less for D=+8, least for D=-8.*<sup>1</sup> A similar result is reported by

<sup>1</sup> The precedence which D=+8 takes over D=-8 may possibly be

Wolfe (p. 556). We may be inclined to doubt, however, whether this fact signifies that judgments are passed with any greater accuracy and confidence when  $D=0$ . For, leaving introspective evidence out of account, the Table shows that, with  $D=\pm 8$ , the most frequent error is the judgment 'equal.' We may, therefore, suspect that there exists a general tendency to give this decision in certain conditions of doubt,—conditions in which the degree of uncertainty is not sufficient to cut off the process of judgment entirely, *i. e.*, not sufficient to be actually registered as 'doubtful.' From data to be presented later, we find that of the correct judgments of 'equal' and 'higher,' the same percentage, 76, are certain: only 66 per cent. of the correct 'lower' judgments are also certain.

2. *The errors.*

(a) *The errors in the order of their frequency are  $=- =$ ,  $+- =+$ ,  $=-$ ,  $-+$ : the last four in nearly the same frequency.* We have just remarked upon the relatively great frequency of the first two errors, due to the tendency to pronounce two impressions alike when the difference between them is not clearly made out. We shall see the force of this point when we discuss the introspection of the subjects.

(b) *The frequency of the error  $=-$  increases nearly uniformly with the time-interval employed. It is the smallest source of error at 2 seconds, the greatest at 60.* It is very difficult to see how this fact could be explained by Wolfe's theory<sup>2</sup> that the memory image, as it declines in intensity and clearness, is underestimated in pitch. Now it is true that our total  $=+$  error is 86 as against 82 for  $=-$ , but the former error exhibits no gradual increase with time, although it is entirely reasonable to suppose<sup>3</sup> that increase of the time-interval would emphasize gradually any such error of underestimation. The possible solution that the observers, fearing that the image was flattening as well as losing in intensity, made, as time passed, an increasingly strong effort to hold it to pitch, and thereby actually sharpened it, is shown by our tests to be the true solution in the case of some observers.

(c) *The error  $+-$  is somewhat more common than the error  $-+$ ; neither is noticeably affected by the lapse of time.*

3. *The nine doubtful cases are contributed one each from M,*

ascribed to the fact that, as is pointed out above (p. —), the average *plus D* is really greater than the average *minus D*. Wolfe assigns the precedence to underestimation of the image.

<sup>1</sup> That is, the judgment 'equal' is given when  $D$  is  $-8$ , etc. When  $=$  precedes, it means that  $V=N$ , *i. e.*,  $D=0$  is given.

<sup>2</sup> *Op. cit.*, p. 556.

<sup>3</sup> Wolfe's Table (p. 562) unfortunately does not show the distribution of errors by time-interval.

*W*, and *S*, two from *L*, and four from *F*, the standards being once *e*, twice *c*, and six times *d*. There are 14 doubtful cases in the second half, not indicated in Table I,<sup>1</sup> one from *F*, four from *L*, nine from *S*. Then the standards were three times *a*, once *b*, once *c*, six times *d*, and three times *e*.

4. *Dependence upon practice.* By comparing the results of the first and second half of the work which is represented *in toto* by Table I, it can be shown that, despite the preliminary period designed to familiarize the observers with the experiments, practice does lessen the total number of errors of each type (save that of  $+ =$ , which is increased in the second half of the year's experimentation). The error  $+ =$  is reduced nearly one-half. The total number of right cases is increased for every interval except 20 seconds. This exception is due to extraneous conditions, being directly traceable to the fact that, on the second occasion of this test, one observer was "very hungry," another "tired, cross and sleepy." The practice effect is almost entirely confined to the unmusical observers,<sup>2</sup> thus, the total number of right cases for *M*, *W* and *S* increases from 198 in the first half to 238 in the second, *i. e.*, about 20%; whereas the total number of right cases for *F*, *L* and *Wh* increases only from 298 to 303, *i. e.*, less than 2%. There is no uniformity as regards the nature of the improvement. The chief gain during the second half is for *M*, with  $D = + 8$ ; for *W*, with  $D = 0$ ; for *S*, *F* and *Wh*, with  $D = - 8$  (*F*, by decreasing the error  $= =$ , *S* and *Wh* by decreasing both the errors,  $= =$  and  $- +$ ). *L* shows no practice effect; on the contrary, he loses ground slightly for every type of *D*. We believe that in so far as regularity of quantitative results is desired, it would be advisable to train unmusical subjects by systematic coaching in *sensible* discrimination; *i. e.*, by a series of preliminary tests in which any erroneous judgment is immediately corrected.<sup>3</sup> We did not adopt this course, because it threatened to interfere with the natural development of the judgment consciousness which it was desired to observe.

5. *Dependence upon absolute pitch.* Within the octave employed (512 to 1,024 vibs.) there is no observable dependence upon pitch. This is clear from a glance at the 'total' column of Table II. It is more difficult to assign the effect of the variations in the various values of *D* from the 8 vibs. theoretically given (see p. 417). Apparently the low value of *b*—(6.815 vibs.) does diminish the number of right cases, for in 108 trials it is correctly judged but 52 times; and, what is more

<sup>1</sup> See footnote p. 417.

<sup>2</sup> C. Stumpf: *Tonpsychologie*, I, 321.

<sup>3</sup> On the effect of such a training by the method of partial knowledge, see Martin u. Müller, *op. cit.*, 195-6.

TABLE II.

(Right cases by pitches. (108 cases each.)

STANDARD.	D=0.	D=±8	D=-8.	TOTAL.
<i>a</i>	69	82	69	220
<i>b</i>	77	77	52	206
<i>c</i>	81	60	65	236
<i>d</i>	66	54	69	189 <sup>1</sup>
<i>e</i>	78	70	68	216
Average,	74.2	68.6	64.6	207.4

significant, the error  $-=-$  is recorded 40 times, that of  $-+ +$  but 16. In other words, the uncommonly small objective value of D in this instance favors the judgment 'equal.' On the other hand, the rather large D in the case of *e* (10.212 vibs.) does not increase the number of right cases: there are even 12 more right cases with *a* (7.668 vibs.) than with *e*.

6. *Dependence upon the individual,—the introspection.* The individual variations in the numerical results can be properly understood only in the light of the introspective data, for the variations in the methods of judgment and capacities for retention of different observers lead to widely divergent results under different conditions of experimentation. We shall, therefore, consider in this place not only the quantitative dependence of the results upon the individual observer, but also those questions which can be answered only by the aid of introspection. The two chief questions are: (1) what is the nature and the course of the tonal memory image, and (2) what is the nature of the judgment process?

In order to facilitate the introspection generally, to avoid stereotyping, and to direct the attention upon all the points at issue, a placard containing a full list of these points was hung before the observers, and they were requested to glance over it from time to time between the tests. We believe that the wide range of the topics thus presented accomplished the object intended without introducing the error of 'suggesting' any particular introspective verdict whatsoever. The card read as follows: Image: beginning, timbre, localization, constancy (pitch, intensity, clearness), muscular strains, associations (colors, words, etc.), attention strains. Judgment: time, certainty, terms (tonal, verbal, muscular, affective, spatial). It was, of course, not to be supposed that any large number of these points could be noted in a single introspective report, but they could all be noted in the course of three or four tests. Further, during the larger part of the experimentation, a consultation was held with each observer immediately at the close of the hour's work: his reports were carefully examined, and he was questioned upon the obscure details. Here, also, the utmost care had to be used to coach the observers without 'suggesting' the results to be found. Thus, after hinting at the possibility of a purely 'verbal' type of judgment, *M* reported eight of this sort in the next set of 15. Suggestibility of this kind must be met by counter-suggestion. Three general sources of difficulty were encountered in the early course of the investigation, but they were successfully eradicated. These were (1) a tendency to stop to introspect during the time-interval, (2) a tendency to too long after-introspection, and (3) a tendency to anticipate the relation of the coming V to N, e.g., "This will be 'plus.'"

<sup>1</sup> Compare the large number of doubtful cases with *d*, p. 423.

## A. THE MEMORY IMAGE.

*Observer M.*

The following propositions may be laid down concerning the origin and course of the image in the case of *M*:

1. The standard (N) usually arouses either (a) photisms,<sup>1</sup> (b) strain sensations, or (c) associations (commonly personifications).

Examples are: (a) purple, dark rich blue, thin steely blue, horrid yellowish green, "darkness of the field stirred." (b) "Both tones seemed to be felt in brows." "N high and thin: strain in my head as if trying to reach it." (c) "Far away as if coming through a fog." "Like a tall, well-built woman with dark hair and clean-cut features." "Made me cross, like a gruff, disagreeable old man." "Sharp like a butcher's knife" (visualized). "Extremely smooth and pleasant like a still pond in warm sunshine in summer."

2. After the cessation of N there is a short interval (about one second) devoid of auditory filling. The image then "emerges."

3. The image is almost invariably of the timbre of the tonometer.

The three exceptions noted are: "Image in terms of my voice supported by movement and strain in throat." "Effort to remember N by translating it from tone of instrument to tone of my own voice; strain in throat."<sup>2</sup> "Image had timbre of instrument and my voice."

4. The image is localized (a) commonly at the back of the room, i.e., at the actual source of sound; (b) very frequently, however, somewhere in the head; (c) occasionally, N seems to affect one ear only, and then the image is apt to be localized there.

Illustrations: "Through middle of head." "Just above eyes, inside." "In ears: thought of ears when trying hard to recall it." "N especially strong in right ear, and image rang in right ear all the time. The memory of N seemed to be all in the right side of my head." "N filled both ears as a cork would fill a bottle. I felt as a bottle must when the cork is put in."

5. Variation in the image.

(a) Qualitative variation is but once noted.

"During the interval an 'after-image' of the tone of the previous test returned, and I got mixed up, but at V the real image of this test appeared." A quasi-qualitative shift is thus indicated: "Image almost lost once, but recalled by slight muscular strain and visual aid (eye feeling as if it were going down the scale and running over two or three notes as it neared, passed and returned to the right note)."

(b). (1) Variation in intensity ('fluctuation') is first noted in the six-second interval; it is quite common at 10 seconds. (2) From two to four fluctuations (periodic increase and decrease of intensity) are recorded at 10 seconds, from four to seven at 20 seconds, etc. (3) At

<sup>1</sup> *M* was seated before a window screened by a yellowish green shade, so that the closing of the eyes for each test may have induced a positive or negative after-image which suggested these photisms. The colors observed are, however, too varied in quality and too uniform in their temporal connection with N to be fully explained in this way. While the color clouds rarely play any part in the judgment, other visualizations do so. At times V arouses a photism different from that of N. For a detailed investigation of *M*'s photisms, see this *Journal*, XI, 1900, 377 ff.

<sup>2</sup> In this instance V had the same 'feeling,' and the judgment was based upon these associations.

<sup>3</sup> Here the judgment was made "by throat and vocal feeling."

15 seconds image-less gaps begin to be noted. (4) At 30 seconds the image may have lost so much of its intensity as to be unserviceable. (5) At 60 seconds the image is often gone beyond recall. (6) In order to keep the image at maximal intensity recourse must be had in intervals from 10 seconds up to muscular contraction (attention strains) in increasing degree.<sup>1</sup>

"Great strains in face and neck to hold image" (15 secs.). "Held breath to hold image." "Breathing interferes and causes fluctuation, as it loosens attention to have to breathe" (30 secs.). "Could remember N better when I was not breathing; better after taking a breath than after expiring."

(c). Variation in clearness is easily confused with variation in intensity, but in the longer intervals the obscuration of the image is readily noted.

"The image fluctuated, and each time of its return seemed dimmer and dimmer."

#### 6. Relation of the image to N and V.

(a). A good image may be constructed from a (subjectively) unsatisfactory N. "Image good and strong for such a thin and disappointing tone."

(b). The sounding of V may either (1) revive or (2) dispel the image of N.

"Image disappeared frequently and was faint, but V recalled it stronger than it was during the last half of the interval." "Image driven away by the greater loudness of V."

#### Observer W.

The cue to the radical difference between the nature both of the image and of the judgment of *W*, as compared with *M*, is to be found in the difference in the type of the two individuals. *W* is phlegmatic, *M* vivacious; *W* is distinctly unmusical, *M* rather musical. For *W* the course and nature of the image may be summarized thus:

1. The standard (N) usually arouses (a) pleasantness or unpleasantness, or (b) an organic 'set,' much less frequently, (c) a visualization<sup>2</sup> (never photisms), and very rarely (d) miscellaneous associations (never personifications).

Examples are: (a) "Pleased at N, and said 'now it will not be so hard to distinguish the next one,'" (b) "N caused a sort of shudder, but yet it was not unpleasant." "Caused a twitch in my ear."<sup>3</sup> (c) "Visualized the tonometer." "Saw indistinctly a big round vortex ring with waving circumference, back of me over the tonometer." (d) "Like a whistle." "Verbal association, 'clear as a marriage bell.'"

2. The image never appears at once. The image-less period is ordinarily estimated at one second, but it may be somewhat longer (five seconds), and the formulation of the image takes place so slowly that

<sup>1</sup> It seems very probable that the large increase of the error -- at 30, 40 and 60 seconds is due to an unconscious sharpening of the image during this active effort to hold it.

<sup>2</sup> In contrast to *M*, *W* never has a visualization with V, and has no sort of visual element in the judgment process.

<sup>3</sup> Cf. Stumpf: Tonpsychologie, I, 168 f.

with the two-seconds interval there is frequently no image during this time.

A curious filling of the image-less gap is once reported: "At cessation of N, I heard the operator say 'ready,' visualized him pulling the stop, then the image appeared," *i. e.*, the image appeared only after a recapitulation of the whole experience of its production.

3. The image is always of the timbre of the tonometer.

4. The location of the image is invariably at the back of the room, and is often maintained there by the visualization of the instrument, as above mentioned.

5. Variation in the image.

(a). Qualitative variation is but once reported, and in this case there is rather uncertainty from the beginning than a shift during the period.

"Did n't get first tone well in mind. I had an argument with myself whether it was a certain tone or not, and then I got more and more certain of it as time went on. I used the image in the judgment" (which was incorrect).

(b). (1) Variation in intensity appears as soon as an image appears, *i. e.*, in the four-second interval. (2) The image may be entirely gone at the end of the six-second interval. (3) Image-less gaps of five seconds duration are reported in the 30 second interval. (4) At 40 and 60 seconds images are almost always said to be present,<sup>1</sup> but the greater part of them are rated as 'bad.' (5) Attention strains appear at 10 seconds, and are characteristic of all intervals longer than that.

"Held breath to keep image." "Great frowning to hold image." "Tendency to produce sound in my throat when I wanted to bring back image." "Fluctuation seemed to go about with my breathing."

(c). Two cases of shift in clearness appear to refer to an illusory bettering of the image with time.

"After a period of fluctuation, image seemed to get clearer, more distinct." (40 secs.).

6. Relation of the image to N and V.

(a). V often (1) dispels the image, but (2) more frequently it 'recalls' it.

"Second tone broke up the image." The recall is noted, *e. g.*, in the two seconds interval when no image had formed. Here the sounding of V is said to make an image of N appear. The recall is also noted very frequently in the long intervals when the image has practically disappeared in the meantime. The excellence of a 'bad' (during the interval) image which is recalled at the end of 60 seconds by the variable tone may be questioned. How shall we estimate, for example, the value of the use of the image thus described: "Had an image of the tone pretty well at first, but it fluctuated and I could hear only the high part of it, and could not tell its timbre until I heard V. Then I remembered about how N sounded, and made a judgment by comparing the two tones?" This instance bears out our previous supposition,<sup>1</sup> for it leads one to suppose that the auditory elements ("timbre") of the

<sup>1</sup> There is reason to believe, as will be shown later, that W overrates the excellence of his images in these cases, and that he may consider an image to be present when there is little or no trace of the auditory core, but perhaps simply an organic complex, strain in throat, forehead, etc.

original complex have disappeared, while the organic or strain sensations ("the high part of it") remain and are attended to as the image.

*Observer S.*

1. N usually arouses either (a) photisms,<sup>1</sup> (b) pleasantness or unpleasantness, or (c) associations (largely of visualized geometrical forms, less often personifications).

Examples are: (a) heliotrope, pale green, reddish brown, yellow line on a dark background. (b) "Low and strong and pleasant." Low tones are uniformly pleasant, high ones mostly unpleasant. (c) "Like two curved lines or rather what was contained between them; much clearer in center and growing fainter along edges." "Soothing like cool water, and more like a round ball than a line." "Image seemed like a woman, perhaps a woman's voice." "Visualized a boy blowing a 'squawker,' quite amused."<sup>2</sup>

2. There is always an interval without any auditory filling immediately after N. Its length is variously estimated from a fraction of a second to three seconds, usually at two seconds.

3. The image almost always has the timbre of the instrument.

Once it "seemed in terms of a horn" (with visualization of the brass mouth of a horn). It should be remembered that S usually carries over into the image those phenomena which are aroused at N, so that it would be, perhaps, misleading to describe the image as a merely auditory representation of the clang, *e.g.*, "the image had something spatial about it which grew larger and smaller each time the auditory part fluctuated." Similar illustrations are given later.

4. The location of the image is either (a) in space in front of the head;<sup>3</sup> (b) somewhere within the head, or (c) very rarely, close to the head, but behind it.

(a) "Outside on a level with my forehead, having thus a location but no form." (b) "Felt in throat." "In ear and head." The following is a peculiar combination of (a) and (b) which is frequent. "Auditory image within my head, but at same time a spatial position for it outside." (c) "Back, behind left ear."

5. Variation in the image.

(a) Qualitative variation is extremely frequent with S, the variation being in every case declared a flattening in pitch.

"Image fluctuated with breathing, and flattened slightly. Did not attempt to bolster it up, simply recognized that it was too low and made allowances in the judgment." (D = -8 given; judgment 'equal.') "Pitch fluctuated a little, but I managed to bolster it up just before V came." (Judgment correct.) A quasi-qualitative varia-

<sup>1</sup> Unlike M, S makes these ascriptions with considerable constancy, *e.g.*, standard *a* is nearly always heliotrope; *b* is green, etc. On the other hand, S does not experience photisms outside of these tests. She does occasionally make use of them in the judgment process.

<sup>2</sup> These associations are obviously like the photisms, determined by the general organic reaction or affective result of the standard. Like the photisms, too, they exhibit rather remarkable constancy, so that, while totally unable to identify the five standards tonally, S did possess a rough knowledge of the identity of the standard by dint of these associations, thus, standard *a* is always strong, cool, round, or heliotrope. It must be added that this rough classification of the five tones did not avail in making the finer discriminations required in the tests, with the exception of the instances to be found below.

<sup>3</sup> When the relation of V to N is based upon 'spatial' relations, V is placed with reference to this situation of the image.

tion in quality occurs once. "Image seemed alive and trying to baffle me. I became very angry and determined to get ahead of it. It danced up and down, to and fro, and I tried to make it keep the place assigned to it."

(b). (1) Fluctuation in intensity, even entailing complete disappearance of the image is reported at four seconds interval, and is characteristic of all longer intervals, though the image-less gaps are not common till the intervals of 15 seconds and longer. (2) The fluctuations may be regular, coincident with breathing, or quite irregular. (3) The support of the image by various muscular strains begins at the two-seconds interval, and is a feature of all the other periods. (But see below, 6).

"Held breath throughout interval" (two seconds). "Contraction in my throat, as if getting the pitch by singing, seem to steady the image." "Great strain around eyes to retain image." "Shook my head to keep out distracting thoughts." "Image disappears when I exhale. I sometimes 'catch' it by inhaling quickly and holding my breath."

(4) The auditory image may fluctuate independently of its visual and other concomitants, or they may vary together.

"Image spatial and auditory. Took a definite position and stayed there, though the auditory image often faded away completely." "The spatial setting of the image grew larger and smaller each time the auditory element varied."

(c). Variation in clearness is rarely noted, with the exception of obscurations of pitch, when a tendency to flat is suspected.

#### 6. Relation of the image to V.

(a) The sounding of V (1) usually recalls the image; rarely it (2) exercises an unfavorable effect upon it.

(1) "Nearly lost image, but it came back all right after V ceased." A rather peculiar recovery, in which the reliability of the image thus gained may be doubted, is the following: "Lost image entirely after about three seconds, and did not recover it again till after V had come. All through the interval I sat relaxed, but confident that the image would come back." (30 seconds, D = -8, judgment 'higher'). (2) "Retained image, but was unable to decide between 'plus' or 'equal' because I lost the image too soon after V sounded to be able to compare."

#### *Observer F.*

1. The standard never arouses associative phenomena; there is only an occasional unpleasantness at 'reedy' clangs.

2. No mention is made of an interval after N free from an image, but the image is said to be weak just after N, then "budding out."

3. The timbre of the image is indifferently that of the tonometer or vocal. *F* says he can think tones vocally beyond the range of his voice.

4. The localization is usually in the left ear, less often within the head, occasionally over the tonometer or directly in front; it may shift during the interval.

"Vaguely somewhere on the wall." "Location in head through the interval, then, expecting V, it changed to my left ear."

## 5. Variation in the image.

(a) Qualitative variation is very common, and always in the form of a tendency to flat.

"Tendency to flat resisted by effort. Tendency caused by the presence of a number of lower tonal images in my mind." "Image flattened at least half an octave; it was a vocal image varying with the position of my mouth, throat, etc." "Attempted to replace the lost image by 'sliding the scale,' thought I recognized it when I came to it." "The tendency of the pitch to flat was marked by a feeling that the muscles of the head were being relaxed."

(b) A curious but frequent report was that of the presence of an "unconscious tone." This may be interpreted as an 'organic set' of some sort.<sup>1</sup>

We shall see later that *F*'s judgments abound in 'motor' elements. The "unconscious tone" is the persistence in consciousness of the 'feel' of the place of the tone when all auditory features are lacking. "Image good for half the interval (40 secs.); then while the image seemed to last, no tone was to be found." "Image seemed to lapse before V, yet the sense of strain in my left ear continued, being increased at V." (Judgment *plus*, correct.)

(b) *F*'s images were for the most part but "fair" strength. They tended to fluctuate irregularly, and in intervals beyond 10 seconds to lapse entirely for considerable lengths of time. They were replaced by "will power" generally, though sometimes this is analyzed into "strains in the throat," especially if the image be of vocal timbre.

(c) The image was very often vague even when of fair intensity. Clean-cut images were the exception at all intervals.

## 6. Relation of the image to V.

A lost image may return at the sound of the bellows before V. More often the sounding of V causes the image to disappear.

"Image crowded out of consciousness by turning the attention to V." In one series *F* contracted the habit of letting the image go into "passive attention," in order to have his "active attention" ready for the coming stimulus.

*Observer L.*

## 1. N causes strain and pressure sensations about the head, affective reactions or associations.

Low tones are uniformly pleasant, and are further described as big, round, filling the ear passages; high tones are uniformly unpleasant, thin, penetrating. There are two instances of visualization: "After N was given, a picture of the tonometer and of a musical reed came up, and I saw the sound come from a reed in the box." "N aroused a visual-auditory ideas of a long, lanky 'co-ed' with a voice like this stimulus, thin and 'smudgy.'" Verbal associations are: "Like the sound of the letter *l*." "Like the sound *il* made in the upper and back part of the mouth by a female voice." The strain and pressure sensations (probably contraction of scalp and ear-adjusting muscles and perhaps changes in blood supply) are illustrated thus: "N produced an expansive effect within the head as if something were inside

<sup>1</sup> Cf. the 'organic set' of *W*, the introspection of *S*, 5 (b) 4, and the tone-less image of *Wh*.

trying to force out the forehead." "N produced a quiver of sensation around and above each ear."

2. No mention is made of an imageless gap directly after N.
3. The timbre of the image is either that of the tonometer or of *L*'s own voice, natural or falsetto.

(Standard *a* is said several times to be so low as to be imaged in terms of his natural voice, but this is obviously impossible since its frequency is 612 vibs.) Images beginning in the reed timbre usually become vocal if a strong effort is made to hold them in consciousness.

4. The image is variously localized, in the head, in both ears, just outside the ear, at the tonometer, or nowhere.

The localizations at the tonometer have some significance because the standards are placed there in strata, *a* being invariably near the floor, *e* being invariably near the ceiling, the other clangs disposed with less exactness between these two. As will be seen, this spacing plays a subsidiary part in the judgment consciousness. *L* occasionally converts intensity into distance, *i. e.*, a "waning" image seems "to wander off, far away."

5. Variation in the image.

(*a*). Qualitative variation is but three times mentioned, always taking the form of a tendency to flat.

(*b*). *L*'s images are reported to be exceptionally good.<sup>1</sup> Fluctuation is not reported until the 20 second interval. At 30 seconds the waning of the image is quite noticeable, but it rarely goes entirely, and can be recovered by imagining it as hummed by the voice. Even at 40 seconds the image may persist through the interval without active effort to retain it.

(*c*). Obscuration was not differentiated from lessened intensity.

#### *Observer Wh.*

1. At N the breath is held; associations, always auditory-verbal, are often aroused, and, with certain high notes, aural sensations, described as a sort of reflex pull, are prominent. At the sounding of the bellows for V there is a "peculiar feeling of excitement and expectation all over," and a tendency to call up the image as vividly as possible.

Examples are: standard *e*: "Verbal association, 'peep,' clear, piping, pleasant, easy to keep as an image."<sup>2</sup> Standard *a*, "A nasal, 'blowy,' clang: thought of my nose."<sup>2</sup> "Verbal, 'that's *a*.'"

2. The image "wells up" or forms itself at from  $\frac{1}{2}$  to 2 seconds after the cessation of N.

3. The prevailing timbre is that of the tonometer, but it may be vocal, or part vocal and part tonometer, and it may shift during an interval.

"Kept image clear and steady by making it vocal timbre, not actually

<sup>1</sup> Obviously these estimates are based upon a subjective standard of excellence. It seems likely, for instance, that *L* overestimates, while *F* underestimates, the worth of his images.

<sup>2</sup> It is of interest to note that this preference for *e* and distaste for *a* are exactly opposite to the attitude of *L*.

vocalizing, but hearing a purely centrally-excited humming or falsetto tone." "Image usually tonometer timbre now, but it has a number of vocal associations tacked on to it, *e.g.*, contractions of the pharynx, alterations of expiration, localization in the throat, though all these are frequently only imaged, not carried out peripherally." "Started vocal; changed it arbitrarily to tonometer." "Images of a clear, penetrating timbre are easily held."

4. The image is usually localized at the tonometer; it may also be in the head, throat, ear or nowhere. By attention it may be placed almost anywhere. Often its location suddenly shifts when *V* sounds.

"Image was at the tonometer, held there by purposed visualization of the instrument.<sup>1</sup> At *V*, or at the sound of the bellows for *V*, it shifted to my throat, and *V* placed itself outside my head higher up. *V* seems to belong outside because it is peripherally excited, and higher because it is higher tonally.

#### 5. Variation of the image.

(a). Qualitative. *Wh* exhibits two peculiar phenomena of a qualitative nature, the feeling of a "tone-less" image, and the presence of two or more rival tonal images during the interval. The latter occurrence is extremely frequent, almost the rule in the long intervals. The general tendency of the image is to sharp rather than flat.<sup>2</sup>

"Several times during the interval, I thought I had the image, but there was only an 'organic tone,' a throat contraction and an altered breathing, etc., without any auditory elements. I kept thinking something which swelled up and gradually died out at regular intervals but it was not tonal." "At about six seconds a lower tone, separated from my image by quite an interval, appeared and bothered me." "Several other pitches presented themselves as candidates. I got disgusted, dropped them all, and made the decision without any image." "During interval, I heard repeated several times a little melody of three notes. Two came with each inspiration, and one, longest and strongest, the image proper, with each expiration. The last was coincident with *V*, so judged '*equal*' easily." "Lost my image, so ran up and down the scale: a certain quality seemed most familiar, so I imaged that, and made judgment easily" (and correctly).<sup>3</sup> "Two images after about the 4th second, the new one was higher and seemed to be suggested by an apparent rise in *N* as it was shut off."<sup>4</sup>

(b) Intensive. As reported, *Wh*'s images rank in intensity between those of *F* and *L*. At two seconds the image is faint,<sup>5</sup> not having had

<sup>1</sup> Reference to the tonometer is a very frequent device with *Wh* to artificially "force" the image, *e.g.*, "Got twice a very strong, hallucinatory image by thinking of blowing the tonometer very forcibly."

<sup>2</sup>This tendency is found in such introspective verdicts, as, "*V* way below my image." It is further amply borne out by the numerical tables which indicate that in the intervals of 30, 40, and 60 seconds, *Wh* has a strong tendency to err in the direction which presupposes a sharpening of the image, provided the image is used in the judgment. In conjunction with *F*'s tendency to flat the image, as shown both by his introspection and his numerical results, this individual difference shows the futility of such generalizations as that of Wolfe when he takes it for granted that the image, because of its weakness, will be constantly underestimated in pitch. We do not wish to imply, however, that the qualitative status of the image necessarily influences the decision at all. *Wh*, for example, often gave such reports as, "*V* was way below my image, yet I felt compelled to judge '*equal*' on account of some feeling of familiarity." (Correct.)

<sup>3</sup>The usefulness of an image thus secured in making a discrimination of 8 vibrations after an interval of 40 seconds is clearly questionable.

<sup>4</sup>Compare a similar effect with the bottle tones later mentioned. The rise, at least here, is subjective, as subsequent tests demonstrated.

<sup>5</sup>*Wh* suggests that the seeming faintness, which amounts sometimes to absence of the image, may be due to the fact that since, in this interval, it is so near *N* and *V*, the image suffers from contrast.

time to fully "mature." At four seconds it is steady after it has matured, and does not need to be actively forced. At six seconds general attention strains appear, composed of sensations set up by contraction of the pharynx, of the arms, and by alterations in breathing which is irregular and shallow. There may be a gap without image.

"Heard image sound, stop, start, etc., twice, an exact repetition of the sounding of N."

No image persists through 10 seconds without fluctuation. Usually there are either two or three waves or periods of intensity, the image being strengthened at each expiration.<sup>1</sup> Keen attention to N is a prerequisite for a good image for this period. At 30 seconds, the image is precarious, it suffers from the slightest distraction, central or peripheral, demands urgent attention, is subject to lapses and to qualitative obscuration by the appearance of other pitches. At 40 seconds, it is always unreliable at the end, and usually gone entirely. To hold it in fair intensity for 60 seconds is almost impossible; any relaxation kills it.

(b). Clearness. Variations in clearness are indicated closely parallel to those in intensity. The qualitative uncertainty occasioned by the presence of secondary pitches may also be regarded as a loss in clearness. Clearness may be recovered when lost, as well as intensity; *e.g.*:

"Slight uncertainty of pitch for a while, then it cleared up" (15 secs.). "Got clearer toward the end of the interval" (6 secs.).

Several times artificial devices are used to enhance the clearness, *e.g.*:

"At about the tenth second, I tried to see if I had the image clearly by imaging a lower tone as if on the tonometer, and seeing if I could tell the difference. I wanted to make sure that the image had some determinateness."

6. Relation of the image to N. A good image depends on keen attention to N. If for any reason, N is somewhat faint, the image may yet be steady and clear, though faint.

### B. THE PROCESS OF JUDGMENT.

The analysis of the judgment consciousness is a matter of some difficulty. The reason is to be found in (1) its complexity, (2) its rapidity, and (3) in the close combination of the essential with the many unessential features of the process.

#### *Observer M.*

The following statements indicate the nature of M's judgments.

1. Terms: The judgments may, for convenience sake, be grouped under a number of headings, although it is to be remembered that no hard and fast lines can be drawn and that exact rubrication is not always possible.

<sup>1</sup>This is very commonly reported, *e.g.* "Pharyngeal contractions at each expiration seem to be the natural sort of innervation by which to attend to tones." Later, however, *W*h says "it is perhaps partly accidental because, by taking thought I can make the intensity increase at each inspiration, and, furthermore, the image often fluctuates independently of breathing." Cf. the "innere Singen," mentioned by Stumpf, *op. cit.*, I, 176-7.

(a). Exclusively tonal. This type is very rare, and found in '*equal*' judgments only.

(b). Auditory-visual, more frequent.

"V seemed to fill the place occupied by N and to be a repetition 'out loud' of my image." This type is closely allied to

(c). Auditory-visual-motor, in which the 'placing' is more emphatic.

"Image just appearing when V came and perfected it, for they 'melded'<sup>1</sup> perfectly." "Seems to be an auditory placing together of the tones as one would place two sticks side by side." "V higher in auditory scale; feeling of actually placing it there."

(d). Visual-motor, in which the auditory element is practically negligible. "I placed the notes visually in a ladder scale."<sup>2</sup>

"V fell in place visually just below N." "I could *see* the comparison. Judgment based on this visual feeling, coupled with strain in the forehead." "N was high up in my visual scale (ladder). V took its place below N at once. Judgment was visual and immediate. Later came the auditory verbal formulation, '*lower*.'"

(e). Purely visual, rare.

"N caused a peculiar feeling as if something dark were pressing on my eyes; at the sounding of V, it was lifted, and a slightly blue, bright gray appeared. Knew at once that it was '*plus*.' " "Very light blue color with N. Judgment made by comparing this color with what might be the color of V."

(f). Auditory-motor, rare.

"Judgment made by direct comparison of tones, aided by muscular strain in throat."

(g). Purely motor (strain sensations, usually of eye or scalp muscles).

"Although I saw nothing, I was comparing visually." "Eyes dropped on N, raised on V. Made an easy and certain judgment of '*plus*.' " "Immediate judgment, for at V there was a slight movement of the eyes as though placing one object below another."

(h). Affective (always with other elements).

"Feeling of 'melding' of tones. Pleasant feeling as though something were satisfied."

(2). Dependence of judgment upon the image.

a) The presence of a satisfactory image usually favors the decision, but (b) with the longer intervals, 'certain' judgments are made when no image is present, and, on the other hand, (c) the presence of a good image does not guarantee a satisfactory judgment.

Illustrations are: "Judgment not immediate, but almost so. Image entirely gone [60 secs.], yet V seemed certainly lower" (correct). "Best image I have had yet (20 secs. interval), but V weakened and destroyed it. Judgment immediate, but uncertain [and wrong]; reconsideration did not make it certain."

3. Speed of judgment.

(a). The majority of M's judgments are immediate, *i. e.*, made with-

<sup>1</sup>A word coined by M to express the feeling of '*equal*' judgments. It is, she says, not exactly either 'welded' or 'melted,' but between the two.

<sup>2</sup>This is an early and a very prevalent type. It is found, excepting in a few cases, with judgments of '*higher*' or '*lower*' only.

out conscious comparison (decided always before V has ceased sounding, one second). The image may be present or not. The greater part or 73% of the immediate judgments are correct. This type prevails when  $D=0$ , 68% of the judgments then being immediate.<sup>1</sup>

(b). (1) Conscious comparison, *i.e.*, the voluntary relating of the image of N to the image of V after V ceases, is less frequent on the whole, but it is more frequent when  $D=\pm 8$ , 57% of these tests being judged by comparison. (2) Judgments involving comparison are oftener wrong than right. (3) Comparison is a clumsy device, used in cases of doubt.

"V different from N, but could n't tell the direction, so I finally decided by trying to recall both tones."

(c). Judgments in which the decision is reversed or debated are not uncommon. There is an immediate judgment, then indecision followed by laborious comparison, and usually by a change of judgment. It is especially interesting to note that in three-fourths of these cases the first 'immediate' reaction is correct.

4. Certainty of judgment.<sup>2</sup> In 269 cases *M* reports 195 'certain' judgments. Of these the majority (127) are correct. On the other hand, of the 74 'uncertain' judgments, the majority (46) are wrong. The certain judgments are distributed thus: when  $D=0$ , 72; when  $D=+8$ , 59; when  $D=-8$ , 64.

5. Judgments of difference without knowledge of the direction of the difference are quite common.<sup>3</sup> They are, for the most part, recorded only when V really differed from N. The judgment 'different' seems to be more easily and more quickly aroused than the judgment 'higher' or that of 'lower.'

"My judgment of difference was immediate, but that of the direction was later and quite slow."

### *Observer W.*

#### 1. Terms.

(a). Exclusively tonal. (1) Qualitative. This is the typical form of judgment for *W*. It is usually characterized by deliberate comparison of memory images of both tones.

"When V came I listened to it, then heard the first (N) again, and then judged the second lower by comparing the two images." "Seemed to identify V with N auditorily." "Judged in tones and then translated into words." This form occurs also when D differs from N, in contrast with the case of *M*. "V seemed to run in on image, and there was a change."

(2). Auditory judgments are occasionally based upon the intensity instead of the quality of V.

For example: at 60 seconds standard *e* was given both as N and V. *W*'s judgment was 'lower.' "No image left, but when V came it

<sup>1</sup> These facts correlate well with the further fact that for *M* there are more right cases when  $D=0$  than when  $D=\pm 8$ .

<sup>2</sup> For further discussion see pp. 37-8.

<sup>3</sup> Reported also by Wolfe and by Angell and Harwood and by Preyer (*Stumpf, op. cit.*, I, 313).

just appeared to me that it was lower than the first by feeling more intense."<sup>1</sup>

(3). *W*'s unmusicalness is well exemplified by the fact that he is often unable to differentiate quality from timbre, and that, accordingly, large numbers of decisions are based upon what he terms a difference in timbre.

We have already mentioned that the reeds used were carefully selected to avoid any such differences, but convincing proof of the subjective nature of this alleged distinction is afforded by the fact that in the cases when *D*=0, *W* frequently reports "2nd more reedy," and again in the repetition of the same standard and variable (*e.g.*, *a* and *a*-8), the report is once, "first clearer," and again, "first more reedy." It is likewise impossible to see any uniform connection between *W*'s estimate of the timbre and his decision. To be sure, he says once "2nd had that reedy quality more and, hence, is *lower*," but on the same day he makes several judgments of '*higher*' when the "second is more reedy."

(b). Auditory-visual, but (unlike *M*'s) with the visual features subordinate and inessential.

"Almost always (?) when I judge I visualize the tonometer and bellows." "Deliberately compared, and saw keys of a piano."

(c). *W* has no visual-motor or purely visual judgments.

(d). Auditory-motor, rare.

"I know how the sounds sound exactly (?), but just can't say whether it should be '*plus*' or '*minus*.' I tried to determine by articulating."

(e). Motor.

Both *N* and *V* often occasioned a "twitch in the ear." *W* thinks these sometimes influence his judgment; if the second twitch were stronger he would certainly say '*higher*'.

A sort of organic basis of judgment is once or twice found.

"At *N* felt a nervous feeling go through my whole body. When *V* came I said it did not feel at all like the first. I think I compared the feelings."

(f). Affective.

A single doubtful use of the affective reaction as a basis for judgment is this. "*N* caused a twitch in my ear. *V* sounded better and softer to the ear, so I at once judged 'lower.'" This instance may be, perhaps, reduced largely to intensity. Like *M*, *W* is most pleased by 'certain' judgments, but, since most of his certain judgments are based upon a process of comparison, he does not report that pleasure in quick, flash-like judgments which we have noted in the case of *M*.

2. Dependence of the judgment upon the image.

The doubtfulness of *W*'s estimate of his images makes this point difficult, but it is safe to say that (a) judgments may be formed after the image-less two second interval, though possibly the image does get formulated in the judgment, and that (b) judgments made by sudden impression, without the presence of any image, are quite rare.

We have already seen that the auditory excellence of the image

<sup>1</sup> It is probable that this error of mistaking the intensity of *V*, as compared with the remembered intensity of *N*, as an index of '*lower*,' accounts for the peculiar prevalence of this judgment in the longer intervals, *e.g.*, 10 out of 15 cases at one sitting. Here again is evidence against Wolfe's appeal to the lessened intensity of the image as a source of the error =  $\pm$ . (Note our previous discussion, p. —.)

reported is probably questionable. The following is an instance: "Fell to noticing a twitch in my throat, and thus lost the image, and then the image got lost in a song, but at the judgment I had both tones (N and V) in my head to compare." (60 secs.)

3. Speed of judgment. It is difficult to classify *W*'s judgments on the basis of speed.

(a). When  $D = \pm 8$ , it is usual to have a quick judgment of difference, and a slow one of direction.

(b). Really immediate, flash-like judgments are very rare.

Even in his so-called 'quick' judgments *W* compares the two images. Thus *W* differs from *M* in every point under this rubric.

(c) Outside of the hesitancy in assigning the direction of a difference, just mentioned, the chief debated judgments waver between 'equal' and 'lower.'

An example of a less frequent class is the following: "I said quickly 'this is plus or equal,' and then reasoned that saying *equal* was only because they seemed almost *equal*, but that V was really a little *higher*. This all quick. Had images of both to compare."

4. Certainty of judgment. *W* has less 'assurance'<sup>1</sup> than *M*, yet the majority of his judgments are 'certain.' Contrary to *M*, his assurance is greater when  $D = \pm 8$  than when  $D = 0$ . The majority (59%) of the certain judgments are correct; the majority (58%) of the uncertain are wrong. Uncertainty increased markedly after the 15 seconds interval.

5. Judgments of difference without knowledge of its direction are extremely common when  $D$  is 8, even with the short intervals.

Instances have already been noted. *W* suggests that this may be due in part to a confusion of the two images while they are being compared. "Compared the tones, knew they were different, but had trouble in deciding *which* was high and *which* low."

### *Observer S.*

#### 1. Terms.

(a). Tonal, very frequent, especially in long intervals, with all forms of  $D$ .

"Convinced myself of the '*plusness*' of V because it did not seem to harmonize with N." "Thought of scales as I had heard them sung, and this seemed like the interval c-b as one sings down the scale, and so I judged V *lower*" ( $D=0$ ). "Equal judgments usually seem to chord or harmonize tonally."

(b). Auditory-visual, infrequent.

(c). Visual, not common.

"N caused pale bluish-green, and V was the same. Recognized equality by color." "Heliotrope patches all through image and interval. These were reinforced by V, so said 'equal.'" By the addition of the place relations this type merges into (d).

(d). Visual-motor.

"N had a certain definite length, breadth and thickness, and V seemed to fit over it." "Image seemed like a horizontal line, and V

<sup>1</sup> Assurance is measured by the number of times 'certain' is recorded, without heed to the correctness of the decisions.

was placed in the same position. Made the judgment in these terms, though uncertain because the auditory relations did not seem to correspond with these." (Judgment correct.)

(e). Auditory-motor.

"V placed itself on N, and I made the judgment in these terms, though the auditory elements also entered in."

(f). Motor.

"I had a certain position for N, and I seemed to put it there, and felt it would stay there all through the interval. When V came it took a higher position without any effort on my part."

(g). Affective elements appear often in the judgment process, but they do not constitute an essential part. *S* has pleasure in 'certain' and generally in 'equal' judgments.

2. Dependence of judgment upon the image.

(a). The large majority of *S*'s judgments make use of the image either in its auditory form, or, less often, in its visual setting (place, lines, color, etc.). Conversely, the lack of the tonal image works the most damage.<sup>1</sup>

"Held spatial position of the image, but lost its auditory portion. When V came I could make no judgment because it was auditory, while my image was only spatial."

(b). Only a single instance of a sudden imageless judgment is reported, and that felt uncertain.

"Judgment an impression, not a decision." On the other hand,

(c). Occasionally a good image may be present without insuring a decision.

"Good attention, and good image, but I simply could not make up my mind between 'equal' or 'different.'"

3. Speed of judgment.

It is almost useless to speak here of the speed of *S*'s judgments, for unfortunately only 109 out of 270 tests contain the introspective indications required. Of those reported, however, it may be said that (a) slightly more judgments are compared than immediate, and (b) the majority of the immediate judgments are correct while the majority of the slower, compared, are incorrect. (c) A sort of comparison coupled with the method of exclusion is a curious feature of *S*'s judgments. With  $D = -8$  it is so frequent as to be the rule rather than the exception. Almost always the result is correct.

"Compared the images several times. Decided they were not *equal*, and V was not *higher*, hence it must be *lower*." "Always have trouble with the 'minus' judgments, and have to argue them out."

(d). Another very common and peculiar feature with *S* is the comparison of the feeling of the present relation of N and V with that of some just previous test or tests. This is a part of the many schemes (singing descending scale, visualizing piano keys and scale, etc.) used to keep the categories 'equal,' 'higher,' 'lower' distinct, for owing to her unmusical nature *S* has apparently no deeply ingrained 'feel' for these relations.

<sup>1</sup> *S*'s quantitative results, which are extremely poor, are to be laid to poor *sensible* discrimination rather than to a poor tonal memory. Cf. Stumpf, *op. cit.*, I, 289.

Examples are: "After recognizing a difference, I said '*minus*,' influenced by my two previous judgments of *minus*." "Judgment slow; thought first that the two were *equal*. Then thought of test 2 (third before this), and compared the two impressions (of 2 and 5). Then decided that V was *higher*." "This combination felt different from the preceding test ('*equal*'), and felt high rather than low, hence '*plus*'" (correct).

4. Certainty of judgment. (a) The amount of certainty was recorded in but 232 of the 270 tests. Slightly more than half (128) are 'certain.' The majority of these (76) are correct. The objective accuracy of the 'uncertain' judgments differs from the results of the other observers in that more, though but very slightly more, are correct than incorrect (53 correct out of 104 uncertain).

If we ask the reason for this, it is easily found in the method of making '*minus*' judgments just mentioned. The figures show that when  $D = -8$ , the majority of the 'certain' judgments are wrong, and the majority of the uncertain judgments are right. *S* makes many of her '*minus*' judgments by the method of argument and exclusion; they are troublesome, hence uncertain, but they are oftener right than wrong. Omitting these peculiarly constructed '*minus*' decisions, the conclusions found for the other observers hold good for *S*.

(b) An interesting feature with this subject is the fact that writing down the judgment, or repeating the tonal interval several times, often brings on a feeling of certainty which was not present when the judgment was made.

"Thought this interval (tonal) did not seem exactly like the previous one ( $D = +8$ , judgment '*minus*'). Reflected that this might, however, be right, my previous judgment wrong, so gave the judgment '*minus*'." ( $D$  was 0.) After writing it down, I felt very positive that I was right."

5. As with the other observers, judgments of difference are more quickly and more easily made than judgments of higher or lower. This occurs only when  $D$  is really  $\pm 8$  vibs. With *S* it may even be said that judgments of higher or lower are, as a rule, made only after a preliminary assertion of difference.

6. An isolated instance which illustrates the automatic nature of the judgment consciousness as it is created by the conditions of experimentation is afforded by *S* who, while attending to the image during a long interval, mechanically passed a judgment of '*higher*' when a street car bell rang outside the building, very much to her surprise and amusement.

#### *Observer F.*

1. Terms. *F*'s judgments are of two types, an auditory and a motor, with or without an auditory fringe.

(a). Auditory. This type is always found with judgments of equality. V is felt to be simply a re-enforcement of the auditory image. Auditory-verbal phrases such as "That's higher" may be present in judgments of difference, but they are secondary.

(b). A single instance of a visual component in the judgment consciousness is the following:

"Saw image as a line in the space before me, and then V as another line shooting just below it whereupon the old one faded from view. At the same time a sense of relieved muscular strain was noted." We are inclined to class this under the motor type and consider the visual element as the result of some suggestion from the other subjects of visual proclivities.

(c). The auditory-motor or motor type is meant to embrace judgments which are characterized by pressure, strain, and organic sensations of any sort which combine to place the tones spatially in a vague manner. This type is always found with judgments of higher or lower.

Examples are: "Judgment conditioned by a loosening of the muscles (scalp?) on the left side of the head." "Based upon a further tightening of the muscles of the ear already 'set' for the pitch of N." "Recognition a moving of the head up and forward." "My 'set of the ear' means not only strain sensations, but also, apparently, an expectation of a certain sort of pressure. A low note gives a broad dull pressure, a high one a stronger pressure. In a 'plus' judgment I feel this change." "Judgment accompanied by a pressure upward in the head."

2. Dependence of the judgment upon the image. *F* exhibits an irregularity difficult to explain, for

(a) many judgments are passed easily without the presence of an auditory image, but

(b) often the absence of an image precludes any attempt at a decision. It may be that in the latter case whatever serves to represent the image in (a) is also gone.

3. Speed of judgment.

(a). Of the cases reported the majority are immediate, *i. e.*, passed within one second and without comparison. There are 202 such instances and 164, 82%, are correct. This type is most common when  $D = +8$ .

(b). Deliberative judgments are most frequent when  $D = 0$ . Only 23 out of 40, or 57%, are correct. *F* contributes one peculiar case of a very slow decision in which there were nevertheless, no image and no comparison.

(c). There is but one instance of a debated judgment.

"At first it seemed *equal*, and then suddenly recognized it as *lower*, and was certain."

4. Certainty of judgment. In 266 cases *F* reports 171 'certain.' Of these 145 were correct. 55 of the 95 uncertain cases were wrong. Certainty was greatest when  $D = +8$ , least when  $D = -8$ . Usually *F* had three or four uncertain tests in a group, perhaps indicative of a temporary lapse of attention or of a temporary loss of confidence.

In one test "V was higher, hence judgment instantaneous, but it was so much higher that I knew image must have flattened, so I was uncertain."

5. *F* never confuses the direction of a difference.

#### *Observer L.*

1. Terms. *L*'s judgments seem, perhaps as a consequence of his ex-

cellent images, to be substantially all of the auditory type. When other elements are present they are subsidiary.

(a). Auditory. These judgments may be quick, but they involve the presence of the image and a rapid observation of the relation of V to this image as tonal sensations. In the few cases reported in which the image was lacking just before V, *L* thinks that it must have "popped back" and thus entered the judgment process. Whether this is not the result of the logical bias in favor of comparison which we have already noted in *L* is very doubtful.

(b). Auditory-visual type, but once reported.

"Process of judgment involved a visualization of a piano keyboard. Tones were seen to be apart, V above N."

(c). Auditory-cutaneous (?). *L* often mentions that the sensation around the ears, which is external and quite pronounced, starts at N and gradually fades during the interval. If V=N, this sensation is picked up or re-enforced in a noticeable manner; if  $V=N \pm 8$  vibs. this sensation is not intensified. At any rate it is a secondary phenomenon.

(d). Auditory-motor.

"There was a distinct representation of V being vertically above N." "Image localized just outside the ear. Thought, if V is the same, it must come right to the same locality, and it did."

(e). Affective elements appear only as a pleasantness at judgments of equality, especially if the tones were also low.

This pleasantness may account for the fact that *L* makes the error 'equal' for 'plus' 17 times as against the error 'minus' for 'plus' 4 times, and the error 'equal' for 'minus' 49 times as against the error 'plus' for 'minus' 10 times.

2. Dependence of the judgment upon the image. As already hinted, *L*'s judgments are unique in the constant use of the auditory image.

An interesting feature in this connection is afforded by his description of the relation of the judgment and the image in fairly long intervals. Following N the image of the clang itself ensues, first "wide" (strong), then "narrowing to a point." "When the point is almost reached I renew the image, so that it is wide again, by executing some imaginary humming for a brief time. If N comes when the image is 'wide,' judgment is easy, otherwise more difficult."<sup>1</sup>

3. Speed of judgment. Data sufficient for numerical results are lacking. At first *L* insisted upon deliberate comparison. Later he reported many rapid judgments, always auditory and with the presence of the image; the deliberative judgments<sup>2</sup> being exhibited only

<sup>1</sup> If we add to this description the further fact that such a process of renewal takes place according to *L* about three times in a .40 or .60 second interval, we have some facts not unlike Wolfe's phenomenon of periodicity. The likeness is enhanced by the fact that *L*'s curve for right cases shows a peak at 15 and, more noticeably, at .40 seconds. It seems plausible, then, that *L* represents a type of observer similar to those of Wolfe, using in the judgment an image which, either voluntarily or involuntarily, is renewed at intervals of time approximately constant for the same individual.

<sup>2</sup> The distinction is this: in the rapid judgment the image is present. As soon as V sounds it is known to be equal, higher or lower than the image. In the slow, deliberative judgments, exhibiting true comparison, no decision can be reached until, after V has ceased, the attention is turned alternately to the image of N and to the image of V. The first type is the more common with *L*, and, save when  $D=-8$ , the more accurate. It is never uncertain.

in difficult tests, whether because V and N seemed only very slightly different, or because some distraction had weakened the image.

(b). Debated judgments are not met with.

4. No quantitative statement of L's certainty is possible owing to the lack of introspective evidence. One can merely say that his assurance was far greater than his correctness.

5. L never confused the direction of a difference.

*Observer Wh.*

1. Type of judgment. Wh's judgments are nearly identical in type with those of F, being almost uniformly auditory, not in the sense that the variable tone is compared with the image of the standard, but in the sense that it is this *tone* V which is judged to be 'equal,' 'higher' or 'lower,' and not a color, or pressure or other sensation. But, it must be added that the position of V as an auditory sensation is for the most part determined by other than auditory elements, viz.: by those sensations which we have, for convenience sake, grouped under the term 'motor.'

(a). Purely auditory. Notably in cases of equality, V simply reinforces the auditory image. Rarely the auditory judgment is verbal.

"Judgment took one second, not to compare, only did n't feel sure till I had put the decision into words and said '*lower*.'"

(b). Auditory-motor. Judgments of either 'higher' or 'lower' almost invariably are based upon some more or less distinct spatial relation between the image and V, or upon an alteration of strain at V without any reference to either the pitch or 'place' of the image.

"'Minus' because of a distinct feeling of depression about my arms and chest." "Some sort of drop in my throat as well as a different external spacing for image and V. This spatial difference is certainly in consciousness before the fiat of judgment itself, whether it be its essential basis or not." "I hold the image steady at a certain point in my throat or externally, and in judgments of '*minus*' or '*plus*,' V comes in above or below this point." "V came into same space in my head, so judged '*equal*.' This is unusual; there is not apt to be any spatial reference in the equal cases." "V considerably separated from image, further from me and perhaps to the right; a sort of 'here versus there' feeling."

(c). Auditory-visual-motor. There are two rather hazy instances of visual components.

"V lower vertically, in a different place visually." "V farther to right, perhaps with a vague association of a piano keyboard."

(d). Unanalyzable. Certain judgments, especially at the end of long intervals are made, as Wh puts it, "by catching at straws;" such decisions are difficult of analysis.

"Judgment slow. Thought it was '*equal*,' but at the last moment I had an irresistible impulse to put down '*minus*,' though I don't see why this impulse came." (Correct judgment.) "The feel of familiarity which touches off the judgment of equality seems to resist further analysis."

2. Dependence upon the image. Wh's introspection is uniform in

showing that keen attention to N is of importance to the decision, but that the condition of the image when V sounds is of secondary significance.

"Good image, but judgment took about 4 seconds, and was uncertain" (and wrong). "No image at all at end, but judgment very rapid and certain." "V was far below my image, yet I felt impelled to judge '*equal*' on account of some feeling of sameness not further analyzable." "Image split up into two, and I gave up trying to hold either one. V had feeling of *belowness*, no shadow of a comparison."

3. Speed of judgment. *Wh* found it very easy to subdivide the speed of judgment into several categories,—instantaneous, very quick, slow, deliberate comparison. The rate termed "slow" belongs in classification to the 'immediate' group, for it implies a time of about one second, and, what is of importance, does not imply any trace of comparison of images.

(a). Thus grouped, *Wh* has 220 immediate judgments, of which 194, 88%, are correct. Immediate decisions are slightly more common when  $D = -8$ .

(b). The 'compared' judgments number but 35, of which but 24, or 65%, are correct.<sup>1</sup>

(c). Judgments in which the decision is reversed or debated are occasionally found. These are almost always cases in which there is an instantaneous judgment for '*minus*' or '*plus*,' followed by a doubt and a fear that it might be '*equal*' because the difference is so small.<sup>2</sup>

4. Certainty of judgment. *Wh* had 200 certain, 70 uncertain judgments. The correlation of assurance and correctness is shown clearly, since 182 of the certain but only 45 of the uncertain cases are correct. There is greatest certainty when  $D = +8$ .

5. Judgments of difference without knowledge of its direction are infrequently reported, perhaps a half dozen in all.

In three of these cases the difference was finally judged correctly, *e.g.* "Knew difference at once, but had to compare tones to get its direction." "Judgment certain and quick, but it seems as if I noted the difference before its direction. Very vague spatial *belowness*."

### C. SUMMARY OF THE INTROSPECTION.

In the light of the fairly bewildering individual variations just recorded, one can but hesitate to generalize. The following statements are put forth, therefore, only tentatively, not even in the hope of covering all the main points of importance, but in the endeavor to present a sketchy outline of the course of the image and of the nature of the judgment process.

<sup>1</sup> We should hardly expect *Wh* with his extensive practice to show a predominance of wrong cases with deliberated judgment as do some of the observers.

<sup>2</sup> This seems an exceedingly apt illustration of the use of the image in the judgment. The decision for '*minus*' or '*plus*' is based upon a 'feel,' a sudden relaxation of some muscles or a 'motor' spacing. There is in that moment no thought of the tonal relations of the variable to the standard pitch; only in the next pulse of consciousness does the auditory relation come into the focus of attention, if it comes at all, and only then does the doubt of the decision appear. The first decision is the one commonly recorded, and nine times in ten it is correct.

(1) The tonometer clang arouses a wide-spread reaction, adjustments of the organs of hearing, pleasantness or unpleasantness, visual, verbal and other associations, often of considerable vividness and detail, and organic 'sets' of various kinds. These supplementing processes help to give the auditory image an individuality; their nature, prevalence and distinctness depend upon the constitutional tendencies of the observer.

(2) Not until a noticeable interval after the stimulus does the auditory image appear. It then swells suddenly out into its maximal clearness and intensity, in the timbre of the stimulus, localized at the instrument, and usually devoid at first of all those adjuncts just mentioned.

(3) Left by itself it then decreases in intensity and clearness. To offset this, the observer has recourse to various memorial aids; he visualizes the instrument, contracts his throat with incipient humming (changing the timbre and localization of the image), and exhibits all those muscular phenomena which characterize active attention, with emphasis also upon certain similar phenomena (notably in connection with respiration) which are felt to be especially effective for attention to an auditory image. Despite these efforts, attention must wane, and with attention, the image. It suffers most noticeably in intensity, less in clearness, and least in quality (here by tending to flat or by getting mixed with other auditory images). Some observers exhibit a long inaccurate retention, others a shorter but more accurate retention.<sup>1</sup>

(4) As a rule the image, under the conditions of our tests, is of little avail for discrimination at the expiration of 30 seconds, while it is very often entirely gone at 60 seconds.<sup>2</sup> This decline and loss of the auditory image does not necessarily imply a corresponding decline and loss of the various supplementary features which played a part in the identification of N

<sup>1</sup>C. Stumpf: *op. cit.*, I, 77.

<sup>2</sup>This is quite contrary to the conclusion of W. v. Tschisch, who says (*Dritter Intern. Cong. f. Psych.*, Munich, 1897, p. 108): "Ebenso ist es eine allgemein bekannte Thatsache, dass wir die Qualität von Gehörswahrnehmungen einige Minuten hindurch mit aller Schärfe behalten, während gute Musiker in dieser Beziehung über ein erstauuliches Gedächtniss verfügen." Stumpf's violin test (*op. cit.*, 230-1) is entirely off the point so far as it pretends to indicate the reliability of the tonal memory image. The tuning of a stringed instrument, according to our experience, may be effected with some accuracy, after any amount of elapsed time, by the aid of certain secondary criteria,—tension of the string, sympathetic resonance of the other strings, etc. Compare Bentley's results already cited, to the effect that brightness images could be recalled better at the end of five minutes than at the end of one minute.

and which may have persisted in the background, now to become themselves the objects of attention.

(5) When the comparison stimulus sounds, it is, under favorable conditions, immediately known to be 'equal,' 'high' or 'low'; this whether or not there is at the moment any trace of the auditory image in consciousness.

(6) If the image is present and V is identical, the experience appeals to the observer as distinctly auditory, V re-enforces, or flows into, the image; if the image is not present, the experience may still feel largely auditory; V is the same *tone*, a familiar *tone*.

(7) If V differs from N, the process is not, as a rule, felt to be so largely auditory; the attention is entirely taken by a complex 'something' which stands for 'high' or 'low.' (We use these terms advisedly in place of 'higher' or 'lower.') What the 'something' is, depends upon the individual; its core is usually a complex of strain sensations, its remoter elements visual or organic.

(8) Sometimes there is a feeling of difference not standing specifically for either 'up' or 'down.'

(9) If V fails to engender either the reaction of familiarity or of specific difference, the observer resorts to auditory comparison, *i. e.*, he hears the image of V alternate with the image of N. The resulting decision is usually uncertain and very apt to be incorrect.

(10) Pleasantness is the correlate of 'certain' judgments, not of any one of the categories 'equal,' 'higher' or 'lower.'

(11) The verbal formulation arises only after the decision has been made otherwise.

(12) The relation of speed of judgment to certainty of judgment is summarized conspicuously in Table III; that of certainty to correctness in Table IV; that of speed and immediacy to correctness in Table V.

TABLE III.  
*Correlation of Speed and Certainty.*

Observer	IMMEDIATE		COMPARED	
	Certain	Uncertain	Certain	Uncertain
<i>M</i>	119	9	54	52
<i>W</i>	22	4	69	71
<i>S</i>	42	2	17	48
<i>F</i>	161	39	1	40
<i>Wh</i>	194	24	2	33
Total	538	78	143	244

It must be explained that in Table III the compared cases for *W* include the type which he characterizes as "quick comparison," and that the 17 cases for *S* include many instances in which the judgment is deliberated for the sake only of identifying its "feel" with that of some previous test, but without any comparison of images. *L*'s results are omitted because the data are insufficient. It should be further stated that in the case of *Wh*, the correlation is somewhat more detailed than the Table implies; thus, as a rule, instantaneous judgments are absolutely certain; quick are certain; slow, less certain; and deliberated uncertain. The 24 immediate but uncertain cases of *Wh* are nearly all from the longer intervals. There is an immediate judgment of 'plus' or 'minus,' but the difference is so very wide that there is uncertainty. So these few cases cannot be said to make against the generalization that immediate judgments are correct and certain.<sup>1</sup>

TABLE IV.  
*Correlation of Certainty and Correctness.*

		D = 0	D = + 8	D = - 8	ALL, D'S.		
		r	w	r	w	r	w
Certain		230	60	217	92	202	83
Uncertain		72	91	68	67	96	68

TABLE V.  
*Correlation of Immediacy and Correctness.*

		D = 0	D = + 8	D = - 8	ALL, D'S.			
		r	w	r	w	r	w	
Immediate	Observer*	<i>M</i>	38	8	26	7	15	14
	<i>S</i>	12	3	8	8	5	11	
	<i>F</i>	44	19	67	7	53	12	
	<i>Wh</i>	62	11	62	9	70	6	
	Total	156	41	163	31	143	43	
Compared	<i>M</i>	11	15	12	24	27	17	
	<i>S</i>	2	8	7	9	12	7	
	<i>F</i>	8	10	4	2	11	5	
	<i>Wh</i>	8	4	7	6	9	1	
	Total	29	37	30	41	59	30	

\* Observers *W* and *L* omitted for want of accurate data.

<sup>1</sup> Cf. the results of Martin and Müller, *op. cit.*, 197 ff.

## PART II.

The experimental work comprised under Part II is subdivided into four more or less distinct series.

## Series I.

The first series embraces six groups of 36 tests each with introspection recorded after every four tests instead of after each test as before. The qualitative results gained by this arrangement are not detailed enough to warrant its recommendation throughout a whole investigation. They demand a more substantial backing, such as is afforded by the method of Part I, in which introspection is taken after each test. A single time-interval (10 seconds)<sup>1</sup> and a single D (8 vibrations) are employed throughout. The image is actively held. The tonometer is replaced by the Stern blown bottle apparatus.<sup>2</sup> There are used four standard tones, *a*, *b*, *c*, *d*, corresponding to the settings 2, 10, 18, and 26 of the recording device upon the instrument, and to the pitches 233.6, 256, 276.4 and 300.8 vibr. respectively, and also eight variable tones (*a*, *b*, *c*, *d*,  $\pm 8$  vibr.).

The objects of Series I are to get a fairly large number of tests with a single time-interval, to see whether long practice changes the method of judgment, to compare the results of blown bottle tones with tonometer clangs, and to prepare the observers for tests with the bottle tones by the method of continuous change.

The observers are *M*, *S*, *Wh*, *B* (Miss A. M. Baldwin), and *O* (Mr. R. Ogden).<sup>3</sup>

<sup>1</sup>Ten seconds was chosen because it affords a suitable time in which to operate the apparatus carefully and noiselessly, and because it is a favorable period for introspection.

<sup>2</sup>For a general description, see *Zeits. f. Psych. u. Physiol.*, XI, 1896, 4-12 and XXI, 1899, 361-4. In all the experiments of Part II the bottle is blown by compressed air from a tank in which the pressure is between 1 and 2 kg. per sq. cm., the pressure at the stop-cock being regulated, by manometer guages and a patent valve, at slightly less than  $\frac{1}{2}$  kg. per sq. cm. The slight hissing sound of the current of air may be lessened by a 'reducer,' a glass tube of small bore introduced within the large rubber feed tube where the latter attaches to the projecting glass tube of the bottle. Thanks to this device, the hiss was inaudible at the distance of the subjects. It is essential that the cog-wheels be heavily smeared with graphite to stop the rattle of the gearing, which otherwise not only distracts the attention, but, owing to the difference in the sound between going up and going down, indicates the direction of the coming V. As it was, we found it advisable to 'blind' the observers by simulating movements in both directions whether the actual V was to be 'same,' 'higher' or 'lower.'

<sup>3</sup>The quantitative results obtained from *O* are omitted from the Tables because illness prevented his participation in the work beyond this series, but full advantage has been taken of his introspective reports.

Observer *B* is to be classed as distinctly musical; has taken lessons upon piano and guitar; has done much playing both as soloist and accompanist, especially with the guitar; sings mezzo-soprano; whistles. *B* is very fond of the orchestra; often has centrally excited music, but finds it somewhat difficult to memorize.

### *Quantitative Results.*

(1) The total number of right cases remains practically constant from day to day.

(2) There are very slightly more right cases when  $D = \pm 8$  than when  $D = 0$ , a result quite different from that of the tonometer tests. This difference is, however, due to the difference in the individuals concerned.

(3) Subjects *M*, *S* and *Wh* (who had taken both series) make fewer errors with the bottle than with the tonometer, 413 to 354 on a scale of 540 tests. The manner of distribution of the right cases is the same in both series for *S* and *Wh* (*S* having more when  $D = 0$ , *Wh* least when  $D = -8$ ), but for *M* the majority of right cases shifts from the column of  $D = 0$  to those of  $D = \pm 8$ , largely on account of the predominance in the bottle series of the error  $=$ .

(4) As in Part I, the most frequent error is  $=$ .

### *Qualitative Results.*

All the general conclusions of Part I are confirmed, especially the correlation of immediacy, certainty and accuracy of judgment. On the other hand, this series shows even greater individual differences in the methods of judgment and in the types of error than did the series of Part I. Subjects *O* and *B*, especially the former, being entirely new to the work, exhibit at first a sharp contrast to the better trained observers, but the inequality is soon remedied, and their introspection has the merit of revealing how the methods and standards of judgment of a given individual are liable to alter in a long series conducted under constant objective conditions.

### *Observer O.*

*O* shows the effect of practice upon both retentiveness and discrimination. At first his images are fluctuating and especially uncertain in quality. Later they are held steadily throughout the interval. Moreover *O* exhibits here what is still better brought out in Part III,—the transition from the slow, image-dependent, deliberate type of judgment to the flash-like, immediate, very certain and imageless type. It is an interesting example of the short-cut tendency in mental operations. In this final stage, *O*'s introspection most resembles that of *F* or *Wh*. The image, which emerges in from one to two seconds after *N*, is in the bottle timbre, steady in quality, varying slightly in intensity with the breathing and often supported by "bodily

feelings," *e.g.*, "Felt image in mouth." "Unconsciously represented the feeling of *N* by moving my pencil-point the way it felt." In his judgments of 'higher' and 'lower,' *O* develops a new type, as they are based upon rather widespread strain and organic sensations. "If *V* differs from *N*, it affects my body differently. I have a rising feeling for higher tones, a lowering feeling for lower." There is one good illustration of the effect of fatigue upon the judgment process. "Got inattentive. Had to repeat the images of *N* and *V* alternately two or three times, yet I had good images and the difference was marked and certain, once I had rendered the decision."

*Observer B.*

During the second day's experimentation *B* reports that often *N*, less often *V*, rises in pitch just as the air is shut off.<sup>1</sup> This rise often causes the image to be obscure,—" Didn't know which part of the tone to remember,"—and, it is asserted, is the main cause of whatever hesitancy the judgments exhibit. The image appears after an imageless gap, is in the bottle timbre, located doubtfully in the head, with the usual fluctuations in intensity. *B* thinks that there may be a slight tendency for the higher images to flat, and a slight effort, chiefly facial, to keep them up. *B* has few slow decisions, even from the outset. Unfortunately she is unable to analyze the rapid-certain type, so that the introspective account of her judgments must be confined to a record of their certainty, speed and dependence upon the image. There is little light on the last point. The certain, immediate judgments are made with good, bad and

<sup>1</sup> This phenomenon is also reported a very few times by *O*, and *Wh*, while *M* and *S* merely say that at times the notes seem like a curved line, swelling in the middle, *S* adding that it is a change of intensity. The explanation of this seeming rise is difficult. Very careful trials show that at a certain position of the air-cock, when the air is nearly shut off, the second partial of the bottle tone can be heard with some distinctness. Now since the movement of turning the valve through a quarter-turn occupies but a brief fraction of a second, and since this partial appears only when the valve is passing through a single very limited position in the arc, it is clear that there can be only an extremely brief variation in the color of the tone as it is shut off. This variation may be perceived, subjectively exaggerated in duration, and misinterpreted as a qualitative change. Besides this, there is the possibility that the simple fall in the intensity of the tone, occupying, say,  $\frac{1}{10}$  second, is in itself sufficient to engender the illusion. (Compare the subjective rise in a dying tuning fork tone. Stumpf, *Tonpsychologie*, I, 242 f., 254 ff., II, 237; also incidental reference to rise in tonometer clang, p. 24). If there is any purely qualitative objective error in the blown bottle, it must be a tendency to flat, for if the mercury be replaced by water, or even glycerine, one finds that the thrusts of the air-blast force the liquid, after the first moment of inertia, down the bottle and up into the variator, thus flattening the pitch. We never, however, observed any movement of this sort with mercury, nor was there any observable lowering of pitch. It seems, then, impossible to say whether the rise effect is entirely subjective or an illusion based upon a brief shift in the intensity or color at the end of the tone.

indifferent images; while, on the other hand, poor images sometimes entail uncertain judgments. The solution of this incongruity appears in the fact that the latter condition holds true only when there is general weariness of body, and hence less strenuous attention to *N*. If this be granted, it confirms the principle previously set forth, viz.: that good attention to *N*, not a good image, is the prerequisite of a good judgment. With *B*, the doubtful or hesitating judgments are most frequent when  $D=0$ , almost nil, 2 out of 60, when  $D=+8$ , and quite frequent when  $D=-8$ . It is an obvious corollary that judgments of 'plus' are very certain, rapid and accurate (only one error in 60 tests); and, what is more, the difference is then much exaggerated, *e.g.*, *V* is judged to be a third, a fifth, or even an octave higher than *N*.<sup>1</sup> The introspection does not explain this excellence in 'plus' judgments. We may assume that it is due to some tendency, not further explicable, to pass this decision. 'Equal' was actually pronounced 47 times, 'plus' 72 times, 'minus' 61 times. All certain judgments are made "as soon as *V* begins to sound." A wait of even two seconds would mean a doubtful decision. Fatigue may bring it about that both sorts of judgment take place; there is an instantaneous decision, "founded on impulse," followed by a comparison of the two images. It appears that not only tonal intervals, but also time-intervals are subject to overestimation, for some of *B*'s deliberated judgments are registered as occupying the preposterous time of 10, 20 and even 30 seconds.

Turning to those observers who participated in Part I, we have to inquire what new introspection is afforded by the conditions of the present series.

#### *Observer M.*

*N* causes visualizations less often, blue being especially predominant. Associations are quite frequent, as before: *e.g.*, "Like a cork bursting from a bottle of fermenting cider." "Like cobwebs and dust." "Buzzed in my head like a bee in a paper bag." The judgments are at first varied in nature, but, as practice with the bottle tones proceeds, they settle down into practically two types, the purely auditory for cases of equality and the auditory-visual-motor type for cases of difference. There seems to be much less visual aid than in the tonometer series, and much more muscular aid.

<sup>1</sup>Tonal intervals on the blown bottle are overestimated by all the observers. This fact is, perhaps, foreshadowed in the 'rise' phenomenon just discussed; it is further brought out by the distinctions made by the observers between the "high" "middle" and "low" standards used, although the interval from *a* to *d* is but 66.2 vibs., equivalent in this region to about a major third.

Illustrations are: "With equal tones, judgment does not seem to be spatial, but seems to be a flowing together, like a mixture of two glasses of water. It is thoroughly auditory and not at all visual." "Before V sounds, my eyes, which are shut, are fixed on a level; at V they move, or tend to move, up or down, as V dictates, thus denoting higher or lower." "I can say positively that it is not the image, but the first position taken by V that determines the relation of the two." "I feel or see a raising or lowering when V is higher or lower." There is one curious case of disparity between the 'expressed' and the 'felt' judgment, "Verbal judgment was 'equal,' but mental judgment was '*minus*.'" With the bottle, difference and direction are both cognized at once, with the exception of one instance. Quantitatively the peculiarity of *M*'s results in this series is the frequency of the error— which occurs 15 times in 60 tests. It seems impossible to explain this frequency whether by appeal to the introspection or to the distribution of the errors when D is  $\pm 8$ .

#### *Observer S.*

The introspection is very similar to that of Part I. The tones arouse fewer colors than the reed clangs, but perhaps more general associations of objects, most frequent being steam-boats and trains, from the whistle-like sound of the bottle. "Had a vivid picture of something moving very swiftly, like a train. Saw it begin and stop. This recurred through the interval and V was like it." The apparatus is often strongly visualized to hold the image.<sup>1</sup> In the judgments the qualitative change is several times misinterpreted as an intensive difference only. There are a very large number of doubtful cases,—cases in which, had the impulse toward a decision been followed, the majority would have been correct. *S* is able now to distinguish three speeds of judgment; a very quick, completed before V is half over; a quick, made directly after V ceases; a slow, necessitating two or three comparisons of images. Direction is still cognized after, and less easily than, difference, and in one case light is thrown upon the mechanism of judgment as it is conditioned by what might be called ease of reproduction. "I knew the difference easily, but not the direction. Said 'lower' because it is easier to say."

#### *Observer Wh.*

In general, *Wh* has similar reports to those of Part I. Like *M* and *S* he has more associations with the bottle tones, *e.g.*, "N tight and strained, like a quarrel or some distressing situa-

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<sup>1</sup>*Cf. Wh* in Part I.

tion." "The 'choppy' start of the tones is pleasant, like the plunge into water in diving." "Verbal association—'clownish,' a laughable tone as if it tried to be mock-serious, or to be somebody big in vain." The image is in the bottle timbre, localized at the instrument, and held strongly by visualization of the machine. Toward the end of the series the incipient singing mentioned in Part I becomes less prominent. "No tendency to sing or contract the throat now. The idea occurred to me during one interval, but seemed odd and foreign to my present method, though these tones are within the region of my voice." There is none of the double image effect so frequent before, but instead such effects as these,—"Had an idea that there are really two sorts of images, of the same pitch however. One I try to hold; it is weak and bothers me; the other, clear and intense, asserts itself like an after-image, without volition." In the first few days also there is "an alternation between the bottle image and another one in my own voice." On the first trial of the bottle *W* has very poor judgments indeed, but it is impossible to say whether because of the newness of the tones or because of the loss of practice during the summer vacation. The judgments take place much as in Part I. The following introspections are inserted, as they make the nature of the process somewhat clearer than before. "Some 'equal' judgments have nothing about them but simple familiarity; there is no tonal reference at all." "In this 'equal' judgment, I had an effect of repetition and coincidence, and an association of touching a place on the skin twice, as in experiments on cutaneous localization, in which, if you happen to hit the point stimulated, you know it because it is more sensitive. Just so my auditory apparatus seems more sensitive to a repeated tone." "The muscular strains which give a spatial setting to judgments of difference are certain enough, but very difficult to analyze farther; they seem simply to stand as symbols of auditory rise or fall and are hence very elusive when attended to for their own sake." "When the D is subjectively very wide, the judgment consciousness is apt to be very spatial. The image is (almost) visualized as a thing here, and V as a thing there, about five inches away, to the right and higher, or to the left and lower." "The verbal contents of the judgment, *e. g.*, the words 'plus' 'same,' are not as usual present until some moments after the decision is made." "Fatigue interferes with the images, but seldom with the judgment." "If the image is good and steady, it is a part of the judgment consciousness, not as a standard of comparison, for it is to V only that I attend; moreover, often the images are poor or lacking, but the judgment goes on just the same."

*Series 2.*

This section includes two groups of 36 tests with each subject, 10 seconds interval, but made with the tonometer. For the sake of distribution of practice they are interpolated in Series 1, but may be conveniently regarded as a distinct series. The object is to gain additional data for the comparison of the tonometer and the bottle as sources of sound. The image is, as before, actively held; the observers are those of Series 1, with the exception of *O*.

The most obvious quantitative result is that the shift of instrument diminished the number of right cases in the first trial. In the second, every observer improves; the total number of right cases increases 15%. This increase is most striking for *B*, who had never heard the tonometer before. Her introspection shows that the, to her unusual, 'reedy' color of the instrument obscured<sup>1</sup> at first the purely qualitative variations given; quantitatively this influence shows in the fact that in the 24 tests in which *V* differs from *N*, there are nine errors caused by judging 'equal' instead of 'higher' or 'lower.' But these effects are not limited to *B*; even observers *M*, *S* and *Wh*, who have had one year's practice upon the tonometer, find it very difficult to adjust themselves at once to the change in the stimuli; images are at first poor and uncertain,<sup>2</sup> while the judgments are slowly made, with little assurance or accuracy. As in Part I, the clangs arouse brilliant photisms in the case of *M*, while *Wh* falls back into the habit of contracting the pharynx to hold the image, a tendency which is strong in Part I, but gradually lost in Series 1 of Part II. This tendency seems engendered by the higher pitch, not by the altered color of the clangs. There is also an indication of a shift in the subjective standard of excellence for *Wh*. "I think that what I am calling a good image now is not as a rule up to those termed 'good' last year; perhaps because I don't need the images so much now."

*Series 3.*

This series comprises two groups of 12 tests with each subject, bottle tones, with 40 seconds interval. The object is to get introspections and data for bottle tones for a longer interval than 10 seconds. The observers are those of Series 2; the image is actively held; introspection is written at the end of each test. A ready signal is given just before *V*. The most

<sup>1</sup> Stumpf, *op. cit.*, I, 235. "Aber selbst die Frage, welcher Ton höher, wird bei ungewohnter Klangfarbe schwieriger."

<sup>2</sup> Apparently indicative of a loss of practice in ideating a specific sort of image, rather than a loss of practice in attention. Cf. Stumpf, *op. cit.*, I, 75 ff.

striking fact evinced by the quantitative results is one, confirmative of Wolfe and of Angell and Harwood, which we have already mentioned in Part I, viz.: with a long time-interval the number of right cases for either  $D=+8$  or  $D=-8$  is greater than that for  $D=0$ ; in the present case it is more than twice as great. In other words, with long time-intervals, difference and its direction are much more readily noted than sameness; or, put in obverse form, the two most frequent errors are  $=-$  and  $=+$ . *B* never gives the judgment 'equal' during the entire series; *M* has but one right case in 8 when  $D=0$ , while, with the other observers, positive judgments of equality are relatively very infrequent. Immediate judgments of 'higher' or 'lower' are, on the other hand, in the predominance, and are made without any trace of the auditory image. The image has, for most observers, become exceedingly obscure and faint by about 30 seconds, and is often entirely absent by the 40th second. Assurance is lessened more rapidly than objective accuracy. The following bits of introspection culled from this series throw additional light upon the course of the image and of the judgment process. "Held image by thinking how it would sound if a man were to sing it" (*S*).<sup>1</sup> "It seems impossible to hold image at all well with my head held erect or backwards. I have to lean forward, and if very anxious, to rest my head on my hands with my elbows on my knees. This attitude seems necessary to attention to the image" (*Wh*). "Image mixed up with another higher image, and they recurred interchangeably. Very annoying. *V* seemed to settle the difficulty, as the lower of the two was at once felt to be the right image" (*M*). (*Cf. Wh* in Part I.) "Muscular strains in throat and chest to keep the image in its proper 'plane,' *i. e.*, I held the muscles of my body up to the 'level' of the tone, and then relaxed to the level of *V* when it came." "I believe I never think the tones are equal because at 40 seconds the image has a sort of 'silent softness,' while *V* sounds terribly loud and material, so utterly different that it is hard to see any sameness of pitch, but real difference I can tell easily" (*M*). "Auditory image absolutely lost. *V* immediately noted as 'away below.' *N* must be held physiologically better than it is consciously, but how, it is impossible to say. These judgments are too quick and surprising to analyze. It is a very odd feeling to have no idea where *N* is, and yet feel that *V* is *below*." "Good strong image, but it sharpened slightly. Knew it because *V* was below it, and yet *V* was so strongly familiar that I unhesitatingly judged 'equal' to the neglect of the testimony of the auditory image." "This long interval affects my general assurance, so

<sup>1</sup> Cf. the predilection for low tones and male voices, p. 12.

that while I make very rapid judgments (usually correct also), I don't like to put down 'certain' till perhaps one second after the first impulse comes" (*Wh*).

*Series 4.*

The four observers of Series 2 and 3 are given 36 tests each, bottle tones, 10 seconds interval, but now, for the first time, with instructions to forget N as soon as possible after it is given. To aid in this attempt, smells are employed as distractors. Some 30 odors,<sup>1</sup> both pleasant and unpleasant, consisting of essential oils, perfumes and powders, are enclosed in similar vials with the names concealed. The observers pick up a vial at random (avoiding repetition) and attend vigorously to the odor at the cessation of N. Distraction is maintained, if possible, until V sounds.

We were led to employ odors as distractors, first, by the successful results obtained from them in this laboratory by a previous investigator,<sup>2</sup> and secondly, because our preliminary tests had showed the futility for this purpose of such processes as adding and reading. We hardly expected to attain complete distraction for so long a time as 10 seconds, since the earlier experiments had merely indicated a possibility of distraction for five seconds, but, as Table VI shows, we were happily disappointed. When supplemented by the introspection, this Table gives a comprehensive idea of the effect of distraction. From both sources, the following conclusions may be drawn:

(1) *Distraction slightly lessens the total number of right cases for all observers*, though, it may be added, this effect is not due so much to the loss or impairment of the image as to the time consumed by the shift of 'venue' at the moment V sounds; V fails to 'sink in' at first if the distraction be complete.

(2) *We must distinguish four different degrees of distraction*: (a) no auditory image throughout the interval or in the judgment, (b) a momentary, very faint reappearance of the image once, twice (or very rarely three times) during the interval, but entire absence of it thereafter, (c) an appearance of the image near the end of the interval, persisting into the judgment consciousness, (d) no appearance of the image until V sounds, usually not until V has ceased. The Table shows 84 instances of (a), 33 of (b), 13 of (c), 14 of (d), while the sum of (a) and (b) gives 117 out of 144 cases in which the image is effectually eliminated from consciousness during the period of the decision.

<sup>1</sup> A set prepared by Fritzsche Bros., New York. For the qualities included, see E. B. Titchener, *Experimental Psychology*, New York, 1901, Part II, 125 f.

<sup>2</sup> L. G. Burch, this *Journal*, IX, Oct., 1897, 45.

TABLE VI.  
*The effect of Distraction. (36 cases.)*

Image	None		Momentarily in interval		In interval and at V		At or after V only		Not at V		Total right cases	
	Judg.	r	w	r	w	r	w	r	w		Ser. 4	Ser. 1
<i>M</i>	14	5	8	0	3	0	2	4	27		27	28.2
<i>B</i>	15	9	5	1	4	3	0	0	30		24	31.0
<i>S</i>	10	14	2	0	1	2	4	2	26		17	21.0
<i>Wh</i>	13	4	15	2	0	0	2	0	34		30	33.2
Total		52	32	30	3	8	5	8	6	117	98	113.4

(3) *The degree of distraction attained varies with the observer.* Thus *Wh* has (a) and (b) equally often, never (c) and rarely (d): *B* never has (d); *S* is most easily distracted to the (a) degree. Under the second heading *B* has the image only at the very beginning, *M* and *Wh* later, at about the 6th second.

(4) If one can trust the small number of cases involved, complete distraction is much more damaging to accuracy of judgment than is distraction of the second type. This conclusion is justified by the introspection. The recall of the image at V is of little avail for the purposes of comparison.

(5) *Distraction in short time-intervals produces in an exaggerated manner certain phenomena of judgment previously mentioned as a feature of long intervals, viz.: lessened assurance, a prominence of spatial elements in judgments of difference, and a greater number of immediate, certain and right cases for both  $D=+8$  and  $D=-8$  than for  $D=0$ .*

(6) *The best distractors are those smells that arouse interest, either by calling up vivid and detailed associations, or by being particularly elusive, yet puzzlingly familiar; they may be pleasant or unpleasant.*

Typical introspections are the following: "Image gone entirely, due to the fact that I thought of candied orange slices. Amusing and interesting" (*M*). "Had unpleasant vision of camphor balls, my trunk and a dark closet at Sage. It was curious; I was so interested in the smell that when V came, I forgot that I had to make a judgment, at least verbally. However, when I came to write the judgment, I found that I naturally wrote 'equal, certain.' No possibility of comparison" (*M*). "At the very beginning there was a slight image, but it was lost and did not reappear. The odor seemed familiar, but I could not tell its name, and this kept me busy during the interval" (*B*). "Made a conscious effort to think of the smell, its name, nature, probable origin, etc." (*Wh*). "Succeeded perfectly in keeping the image away by vigorous and constant sniffing and by compar-

ing the intensity of the odor with each nostril" (*Wh*). The remaining introspections concerning the judgment are all from *Wh*. "The 'wave back' of the auditory image seems to come when my first wave of attention to the odor dies low. It is not hard to reinstate the smell consciousness. I have a hazy feeling that this recurrence, brief and vague as it is, may somehow make the judgment easier; that it leaves some effect which would not otherwise be there." "At about the 6th second the image was back for a moment. I thought, 'that's not it.' Judgment was made without image, a wide D, spatial-motor setting, and at once came the thought 'that image *was* all right,' *i. e.*, instead of the comparison process, I really checked the image by the imageless judgment." "Good distraction. Judgment immediate, but not quite so fast as in experiments without distraction. There is no hesitation or comparison, but the feeling does not 'flash out' as it does sometimes. Moreover, after many of the quick judgments I have doubts. Often I almost forget what to write; the judgment consciousness is more fleeting. In the previous test the judgment was certain when made, but uncertain at the time I wrote it." "Judgment just a quick impulse to '*plus*.' As I wrote it down a sudden uncertainty arose. This uncertainty was clearly due to the presence in the fringe of consciousness of some other judgment. If but one judgment arises I am very certain; if two arise with one distinctly predominant, I am fairly certain; if balanced in strength, I am in a state of doubt and considerable unpleasantness."

This concludes our attempt at the qualitative analysis of tonal memory as it is investigated with the use of discrete stimuli and the modified method of right and wrong cases. In a subsequent article we propose still further to examine the judgment-consciousness by the aid of the continuous change method, and to give a general résumé of the results of both methods.



# AN ANALYTIC STUDY OF THE MEMORY IMAGE AND THE PROCESS OF JUDGMENT IN THE DISCRIMINATION OF CLANGS AND TONES. (Concluded.)<sup>1</sup>

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## EXPERIMENTAL. CHAPTER II. (*Continued.*)

### PART III.

The problems previously considered, viz., the nature and course of the tonal memory image and the nature of the judgment consciousness, are in Part 3 examined by the aid of what may be termed the method of continuous change or the method of reaction. The second tone, V, starts from above or below the standard, N, and moves uniformly toward N until arrested by the observer when subjective equality is reached. The method thus differs from that employed in Parts 1 and 2 for (1) a moving tone is used for V in place of the discrete stimulus of the method right and wrong cases, while (2) the judgment is always that of 'equal' and (3) a movement of reaction is required on the part of the observer.

The method is most similar to that of equivalents<sup>2</sup> with the introduction of a time-interval between N and V. It yields two values,  $V_o$  ||| N and  $V_u$  ||| N, these being the averages of the determinations of subjective equality made in a certain number (in Table VII, six) of movements of V from above and from below N respectively. The mean of these two values, taken algebraically, indicates, by its size and sign, the amount and nature of any tendency on the part of the observer to err in a greater degree upon one side or the other of N. This value

<sup>1</sup> For the first article, see this *Journal*, XII, 1901, 409-457.

<sup>2</sup> Külpe: *Outlines of Psychology*, 1895, 56 f. It may be likened also in some respects to the reaction method as described by Stern (*Psych. d. Veränderungsauffassung*, 108 ff.), who says, "das Charakteristische des Reactionsverfahrens besteht darin, dass die Veränderung solange währt, bis die Versuchsperson selbst ihr durch eine Reactionsbewegung ein Ziel setzt." It is hardly necessary to point out that Stern's application of the method was made with a different purpose (the perception of change itself), so that the variable moved more slowly, and not, as in our tests, from a given D toward equality. These points of difference preclude extended comparison of results.

corresponds to the 'true subjective equality' of the method of equivalents proper, but we have chosen to term it the 'estimation value of N.' Finally, the mean of these two values, arithmetically taken, indicates the average distance from N of the upper and lower boundaries of the 'zone of equality.' In a few cases, as the tables show, the signs of the two values of V ||| N are alike; then obviously, the 'average limit of error' coincides with the 'estimation value of N,' and simply determines the center of the 'zone of equality.'

In his use of the reaction method Stern<sup>1</sup> saw fit to subtract a constant value, 0.5 sec., assumed to represent the reaction-time. We have not carried out any subtraction in the present Tables for several reasons.

1. Though the value of the reaction-time is, according to Stern, higher for continuously changing than for discrete stimuli, it decreases as the rate of the variation increases.<sup>2</sup> Since our rate is much faster than any of those employed by Stern, the value in question would be much nearer the simple reaction-time to discrete stimuli than 0.5 second.

2. Stern also includes in the subtracted interval a period known as the 'decision-time.' This is due to an inhibition of reaction, set up by the attempt to secure greater certainty. "Man lässt das Urteil erst eine gewisse Sicherheit gewinnen, ehe man sich zur Bewegung entschliesst; die Anregung zur motorischen Aktion ist bei allmählichen Veränderungen eine sehr geringe." Under the conditions of our own tests, we very much doubt whether this influence is to be reckoned with at all. To be sure we find everywhere evidences of a tendency to premature reaction which is being met by obvious conscious attempts to inhibit it, and this process might seem, on first thought, to be identical with the above-mentioned retardation of the decision. But these are two distinct phenomena. Stern says that the decision-time is "eine, wenn auch *kurze*, so doch nicht ganz zu vernachlässigende Zeit." Under our conditions several tendencies to react may appear and be inhibited before the actual movement, while the interval between each one may be of perhaps one second's duration. It would be manifestly absurd to add these relatively long periods to the observer's reaction-time proper for the purpose of subtraction.

If, however, there should be present a retardation of the reaction of very short duration such as Stern mentions, it seems quite appropriate that this time should be rather included than excluded from the results, for the delay is made for the sake of subjective certainty, and the recorded values will therefore in-

<sup>1</sup> *Zeits. f. Psych.* vii, 1894, 270; xi, 1896, 21; *Veränderungsauffassung*, 109 f.

<sup>2</sup> *Veränderungsauffassung*, 109-110.

dicate simply the point of assured equality rather than the point at which the first intimation of equality appeared.

3. Both the tables and the introspection, as will be more fully shown later, indicate the presence of an uncommonly large error of expectation. This means that the movement of reaction takes place before subjective equality is reached. The method itself offers no satisfactory procedure for counteracting or adequately estimating the force of this error as do those methods in which it is possible to reverse the direction of the steps or movement of  $V$  in half the tests. It seems, therefore, unwise to accentuate this error, already so plainly present, by an increment whose amount can be only arbitrarily established.

4. Neglect to discount a value for the reaction-time would affect merely the absolute values of our Tables; the relative values would be practically what they are now; the 'estimation value of  $N$ ' would be unchanged, save in a few instances.

5. We are not primarily concerned with the quantitative results.

We have, therefore, chosen to present values computed upon the basis of the actual moment of the reaction rather than to manipulate these values by the subtraction of a value whose amount is exceedingly difficult to estimate, and whose influence is perhaps to be questioned in the face of the strong expectation error.

*Instrument.* For convenient work by this method the following changes in the blown bottle apparatus are advisable if not absolutely requisite.

1. The large air storing tank is replaced by a simple device consisting of two galvanized iron cylinders approximately 75 cm. deep and 30 cm. in diameter. The lower cylinder is filled with water, and provided with a pipe projecting above the water within and connected with the bottle system without; the upper cylinder is inverted and arranged to slide within the lower. A weight of 3.7 kg. on the upper cylinder yields adequate pressure and produces a smoother, less hissing tone than the air stored under greater pressure in the large tank.

After 6 or 8 tests, a counterweight of 9 kg. speedily raises the exhausted cylinder, and the experiments can thus proceed with almost no interruption and with far greater economy of energy; indeed, without steam or other mechanically driven pumps, it is very difficult to store enough air for an hour's work by the continuous change method.

2. The smaller crank of the Stern machine is entirely removed. The axle of the larger crank is extended to a length of 130 cm. from the cog wheel, and supported in a rigid journal. The crank itself is replaced by a brass arm 135 cm. long, supplied with a knob-shaped wooden handle. This long crank arm is a necessary help in producing an even revolution of the gearing; the extension of the axle is necessary to permit the lengthened crank to clear the projecting rod of the mercury piston.

3. The armature of a Petzold time-marker is fitted with a light projecting arm of steel, 17 cm. long, carrying two teeth. These parts

are so adjusted that when the observer closes a circuit key, the teeth instantly engage the cogs of the gear wheels so firmly as immediately to stop the movement of the crank by the operator. The advantage of this device over the stop-watch<sup>1</sup> is obvious.

*Method of Procedure.* One of three standard tones, *a*, *b*, or *c* (corresponding to settings 5, 15, and 25 of the apparatus, and to the pitches 242, 270, and 298 vib. respectively) is given with a duration of one second, beginning two seconds after the usual 'now.' After an interval (10 or 40 seconds), a second tone, *V*, is given, which begins 3, 4, or 5 turns of the crank in either direction from the standard setting (*i. e.*, at 8.4, 12.2 or 14.0 vib. above or below *N*), and moves uniformly toward the standard, always at the rate of one-half revolution of the crank (1.4 vib.) per second. When the observer<sup>2</sup> thinks that *V* is equal to *N*, he presses the key which, as was above explained, stops the movement of *N*. The observer dictates his introspection and the operator records the setting of the apparatus in terms of revolutions and hundredths of a revolution, thus giving readings within 0.028 vib. The observer's error is later computed in terms of vibration rate. The observers are *M*, *B*, *S* and *Wh*.<sup>3</sup>

The experiments of Part III are subdivided into four Series, whose conditions are varied in three respects, (1) by using a time interval of 10 or of 40 seconds (2) by procedure with or without *specific* knowledge, and (3) by active attention to, or active inhibition of, the image (artificial distraction).

### *Series 1.*

Series 1 consists of three sets of 18 tests each for each observer at 10 seconds interval. The first set is not figured in the quantitative results because of the rapid growth of special practice which took place at the outset. The third set is taken late in the course of Part III (directly after a series in which the procedure is with knowledge), but is treated in connection with the second, so that Series I, as represented, practically consists of 36 tests for each observer.

In order to make these tests more comparable with those by right and wrong cases, and to avoid the error of expectation so far as possible, the procedure is without knowledge. But this phrase must be used with qualifications. By it is meant that there is no knowledge of the *standard* to be used, of the *amount* of the difference, *D*, of the *absolute rate* or of the *direction*, of the

<sup>1</sup> Employed by Stern for a similar purpose: *Zeits. f. Psych.*, xi, 1896, 20; xxii, 1899, 2.

<sup>2</sup> In this procedure, naturally, but one observer is tested at a sitting.

<sup>3</sup> Dr. W. C. Bagley kindly served as operator for *Wh* in Part 3.

movement.<sup>1</sup> Any test in which the direction of the movement of V is unrecognized is discarded and a new trial given. The direction of V may be known in two different ways: 1st, by an immediate awareness of its pitch relation to N, 2nd, by observation of V itself as it moves. The second is obviously a slower process, and it is correlated with less accurate judgments. This is to be expected since the slower process implies a loss of the position (tonal or otherwise) of N, and since the very effort of observation entails a distraction of the attention from the real object of the test.

TABLE VII.  
*All Values in Vibrations.*

Obs.	D	V <sub>o</sub> III N	m. v.	V <sub>u</sub> III N	m. v.	Aver. Limit of Error.	Estimation Value of N.
<i>M</i>	8.4	0.39	1.23	-1.07	1.51	0.73	-0.34
	11.2	2.74	2.76	-3.38	1.46	3.06	-0.32
	14.0	3.00	2.40	-3.20	2.21	3.10	-0.10
<i>B</i>	8.4	2.26	1.18	-1.68	1.46	1.97	0.29
	11.2	4.45	1.82	-4.26	1.04	4.38	0.10
	14.0	6.83	1.99	-4.93	2.16	5.88	0.95
<i>S</i>	8.4	1.09	2.09	-1.88	2.09	1.49	1.49
	11.2	2.29	2.80	-1.29	1.79	1.79	0.50
	14.0	3.78	0.98	-1.51	1.62	2.65	1.14
<i>Wh</i>	8.4	-1.34	1.37	-1.09	1.09	1.22	-1.22
	11.2	0.90	1.82	-1.54	1.93	1.22	-0.32
	14.0	0.05	0.92	-4.09	1.60	2.06	-2.02

*Quantitative Results.*

Table VII shows the quantitative results of Series 1. From it the following results are apparent:

1. With two exceptions, every value indicates an error of expectation.
2. For all observers, the expectation error increases with the increase of D:<sup>2</sup> this is shown by the progression in the col-

<sup>1</sup>It may be noted that *Wh* was, at least at first, at a slight advantage. He knew that there were three standards, three D's, and that the rate of change was uniform; yet the observers were soon put upon nearly equal footing because (1) the knowledge of the number of standards was of no practical value, (2) the other observers soon came to the conclusion that three (or four) different D's were in use, and (3) they were told early in the first set that the rate was uniform, and that V never started at equality with N.

<sup>2</sup>To anticipate the qualitative discussion somewhat, it may be noted that the two exceptions just mentioned both occur with the smallest D, *i. e.*, under conditions such that a momentary cautiousness or a slight effort to combat expectation will suspend reaction too long and

umn of the average limit of error.

3. The mean variations are large.
4. *M* and *Wh* constantly underestimate, *B* and *S* constantly overestimate *N*. This feature is of itself indicative of some individual differences in the manner of judging, so that we are led to examine the judgment consciousness as it is revealed by the introspection.

### QUALITATIVE RESULTS.

#### *A. Features common to all observers.*

The introspection throws light upon several minor features; *e. g.*, the manner in which the position of *V* is first known, the nature of its movement, the existence of a curious 'after-tone,' etc., besides yielding, what is more to our point, a satisfactory analysis of the judgment-consciousness. The chief matters of interest in this analysis are the direction of the attention, the ultimate basis of the judgment, the influence of expectation, the feeling of assurance, and the nature of the reaction movement. These factors must, for the most part, be discussed in the light of the reports of each observer separately. But in five respects, *viz.*, the knowledge of the position of *V*, the nature of the movement of *V*, the nature and influence of expectation, the 'after-tone,' and the assurance, the reports of the observers exhibit such community that these topics may be profitably discussed at the outset.

*Knowledge of the position of V.* Observers *M*, *B* and *Wh* as a rule knew *N* as soon as it sounded; *S*, as might be expected from her poor sensible discrimination, had more difficulty and frequently relied upon her observation of the direction of the movement to gain her knowledge of the position of the starting point. However, the wider *D*'s offered little difficulty. It is of interest to note that large *D*'s produce in an exaggerated manner the organic shifts which have already been reported as characteristic of the 'higher' and 'lower' feels of compared tones. For example, the slight feeling of relaxation which was noted by several observers in the tests with discrete tones (*D* = 8 vib.) became exaggerated into a very distinct slump or depression when *V* differed from *N* by 14 vib. " *V* caused a sudden feeling of drop, very like the feeling you get when you wake up suddenly thinking you are falling" (*B*). " The recognition of the place of *V* above or below the image is nearly always immediate, and similar to that in

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equality will be passed. Both the observers in question, *S* and *Wh*, note this explicitly; *e. g.*, " Feeling the error of anticipation, I now have a tendency to restrain the reaction. With a small *D*, therefore, the time to equality is so short that I overdo this and react too slowly."

the discrete experiments, except that it always seems to come as a shock or blow, a change of bodily attitude of some sort" (*Wh.*).

*The movement of V.* The variable tone seems practically never to progress steadily towards N, but to move by stages which may be regular or irregular. S, who uniformly experienced a lively visualization of the progress of the tones, was able to illustrate this movement graphically. The following reports will indicate more clearly what is experienced: "V moved slowly toward my image which I kept clearly in mind. When yet a short way off, it jumped to it by a wide step and fused with it." "Jumped to equality on the second slur. I had to react, though I suppose it was too soon." "V came down by a series of swoops. Finally one was almost at equality, but I said to myself: 'wait till the next.' At the start of the next plunge I saw suddenly that it had passed, and I reacted as quickly as possible, but with disappointment at the failure" (*Wh.*) The number of stages depends largely upon the amount of D; when D is 8.4 vibs. the tone usually makes 3 or 4 steps; when D is 14.0 vibs. there are 7 or 8 steps to equality. It will readily be seen that the existence of these stages plays an exceedingly important part in the mechanism of the judgment.

*Expectation.* The existence of a large expectation error is one of the most striking results of the continuous change method. It is very apparent in the quantitative results of Table VII where, with but two exceptions in 24 cases,  $V_o \parallel N$  is represented by a positive, and  $V_u \parallel N$  by a negative sign. This table also shows very clearly that the amount of expectation is largely increased by increase of D. The existence of expectation is also very apparent in the qualitative reports. One of the most regularly recurring features is a tendency to premature reaction. It is scarcely too much to say that in *every* test, the observer experiences from one to more impulses to react before actual movement is carried out. The introspection shows, however, that this expectation tendency is not always due to a single motive. We may distinguish several contributory causes. First, in the case of a large D, expectation may result from the very fatigue of waiting for equality. The pitch interval of 14 vibs. demands, at the rate we have employed, ten seconds for its transition. This is a long period for active attention to the variable tone when the observer has already been taxed with the effort to retain the image, or whatever stands for the position, of N during an empty time-interval of 10 seconds before the variable stimulus appears at all, and when he is still further taxed with the effort to maintain the position of N through the ten seconds dur-

ing which V is sounding. It is small wonder, then, that despite the precautionary check to hasty reaction which the wide D itself affords, the observer should yield to the temptation to "have it over with." This occurrence is frequently reported thus: "With a wide D, I get tired of waiting." "D was wide and the strain on the attention so great that I reacted even with the thought that it was not yet quite equal; but still I felt that I must get through with it." "When D is wide, I now make a distinct effort not to hurry, but still I react too soon" (B). Again the expectation may be set and released at a definite point, this point being determined by an estimate of the amount of the D.<sup>1</sup> In these cases, obviously, the judgment is determined by the lapse of that amount of time, which, it is inferred, should bring V to the point of equality. Here, however, we may regard this process as one phase of the expectation tendency. This influence may determine the judgment quite by itself, or it may modify the natural course of the reaction which would otherwise ensue, *i. e.*, frequently an observer says he felt that V must have reached N, although equality had not yet been attained on the basis of auditory recognition. Illustrations are: "Felt it must be time to react though V was not quite back to what I wished" (Wh). "Was n't quite there, but felt it ought to be, probably from my previous estimation of D" (B).

Finally, there is a simple sort of expectation which is a very potent factor in the judgment consciousness, but which cannot be more accurately defined than a dread of getting past equality. Apparently the feeling is that, once equality be past, one would be helpless, for the moving tone would then be constantly getting *away* from the desired point. Perhaps this interpretation is too much logical, and too little psychological, but, whether or no this much is in the observer's mind, the action of some such motive is very evident from the following examples: "Scared stiff for fear of passing equality." "There is still almost as much excitement now as at first. I can't look at the matter calmly" (M). "I get worried when V approaches N for fear it will get away from me" (S). The experimenter can attest that this expectant attitude is clearly visible by all the usual outward tokens of the keenest sort of attention, which culminates, at least, during the earlier tests, in distinct agitation at the crucial point. Now it would seem very probable that so vivid an expectation would be noted by the observers, and that deliberate attempts would be made to counteract its influence. We have already quoted extracts which show that

<sup>1</sup> This point will be further discussed below when the basis of judgment is mentioned.

such is actually the case. What is most remarkable is that, save in exceptional individual tests, this deliberate inhibition of the tendency to premature reaction is never adequate. When the observer is making a conscious effort to retard his judgment, and when this effort seems to him to have been adequate, or more than adequate (so that he complains that he has passed equality, has waited too long), even then the subconscious tendencies prevail, and an expectation error appears. "With wide D's, I now make a distinct effort to wait" (*B*). "I think I now generally wait a little after V seems at equality to make fully sure of it." "There is an area of equality. If I am excited, I react as soon as I get to it; if cool or confident, I wait till I am well within this area" (*Wh*). Often the natural influence of the wide D to heighten expectation is combated with varying success by the time inference; *i. e.*, that since D is wide, it will take more time to reach equality. The resultant reactions are thus subject to noticeable variations. This is one of the influences which produce such large mean variations. A single case will illustrate. "A very big D going down. . . . I passed through a period of seeming equality, felt it time to react, but hesitated (probably because D was wide and the time then elapsed but short); then, after a tonal *difference*, entered *another* period of equality and reacted" (*Wh*). [Result, still 0.6 vibes. too high.]

*The after-tone.* It will be remembered that the moving tone was arrested by the direct action of the armature of an electromagnet upon the gear wheels: the actual movement was very short, and its inertia was reduced to the lowest point by proper adjustment of the springs controlling the armature; nevertheless, all four observers quite independently noted that after the key had been pressed there was a distinct additional movement of the tone. By listening to this 'after-tone,' observers *B* and *S* quite frequently, *M* less often, decided whether the reaction had been made too soon or too late, and in this manner they evolved a sort of control over their natural expectation error.<sup>1</sup> Typical reports are: "After judgment is made and the key pressed, V has moved some since my decision (*S*). "After re-action, noted after-tone and thought 'I should have waited longer; that tone was nearer the right one'" (*M*). "At the moment I press the key, the tones seem equal; then immediately afterwards I listen to V and see that I did not wait long enough" (*B*). "At judgment, thought 'too low,' but after-tone seemed about right" (*B*). To obviate this peculiar influence, it became necessary finally to put in the reaction circuit

<sup>1</sup> *Wh* noted the tone, but did not use it as a corrective of his judgments.

a rather loud 'buzzer,' which sounded whenever the key was pressed, *i. e.*, simultaneously with the action of the armature clutch. The intensity was sufficient to drown the bottle-tone. The introduction of this noise, however, did not, curiously enough, accomplish the purpose for which it was intended, for despite the sound of the 'buzzer,' *B* and *S* occasionally reported the after-tone. More careful observation then brought out the real nature of the phenomenon. The so-called 'after-tone' is in reality due to a subjective process,—the formulation and execution of the judgment withdraws the attention for a very short time from the stimulus. The observer then hears that portion of the moving tone which sounds after his impulse to react and before the action of the clutch and the noise buzzer stop both the movement and, so far as the observer is concerned, the sound of the variable tone. This explanation will be clearer when the nature of the apparent movement of the variable tone and the influence of expectation are recalled. The movement of *V* takes place not uniformly, but by a series of slumps or slurs. One of these sudden changes may take place just after an impulse to react matures. The general effect of expectation is, we think, to cause the incoming variable stimulus to seem nearer the standard than it actually is. When the test is completed by the decision, the influence of expectation is suddenly thrown off and the observer hears the tone quite distinctly different in pitch from the tone noted a moment before when the key was pressed.

*Assurance.* From the very nature of the continuous change tests, one cannot expect the observers to exhibit that degree of certainty which is obtainable in the tests with discrete stimuli. There the answer was definitely right or wrong. Here only a very happy chance can bring the reaction movement at precisely the fraction of a second when *V* is passing the point of equality. The influence of expectation and of the attempts to counteract it also plays some part in lessening the observer's assurance.

We prefer to speak rather of the observer's assurance than of his certainty, and to retain the latter term for the method of judgment, for, in the present case, no observer can say definitely that his reaction was made at precisely the proper moment; he can only feel an assurance that it is "pretty good," "somewhere near," or "the best I could do." As *Wh* expressed it, there is not a point, but an area, of subjective equality, and that reaction is felt to be satisfactory which is within this area. Even so, the assurance of the observers is never very great. It is often affected either favorably or unfavorably by the after-tone. The following are typical reports: "V not like my image, but the nearest thing that had come."

"Judgment rather uncertain. Thought it too slow at first, then, hearing the after-tone, decided not." "After reaction thought I had only reached the *edge*" (M). "I never get any definite recognition, but I stop the tone when it is near it. Don't usually know the direction of error" (S). "Not just right, but don't know which way the error is" (B). "Decision fair, but not a 'dead-sure' feeling" (Wh).

### *B. Features peculiar to individual observers.*

We have just discussed certain features of the qualitative results of the continuous change method which were common to the reports of all the observers. This discussion revealed the existence of a peculiar after-tone, largely subjective in nature, which was used to control decisions, and of a strong expectation tendency which was fostered by several contributory motives, but counteracted by conscious attempts at restraint. Furthermore, it was shown that the perception of the starting-point of V, and that of its movement, involved practically similar experiences for all observers. The degree of assurance was quite similar for all. One might, therefore, suppose that there would be little room for individual variation in the reaction-consciousness. But such a supposition is too hasty; it neglects the fact that the passing of a single decision is the result of the operation of a very complex tangle of mental processes, of the function of a fairly large number of factors, each of which has its own special influence upon the outcome. Indeed, it seems, in many instances, impossible for the best trained observer to unravel the tangle, and to designate the amount of the influence which is to be ascribed to each of the factors in operation. We must be content if the observer can indicate the striking mental structures in every particular test, and if he can, in the course of a large number of introspective reports, indicate, from time to time, the less obvious structures which are to be found in his typical experiences. In this way, we can hope to obtain, in the first place, a tolerably accurate knowledge of the general process of judgment for each observer, and, in the second place, an account of the one or more particular features which have been prominent in each single decision.<sup>1</sup>

<sup>1</sup> One of the most interesting things which appeared in our reports was the tendency of the observers to specialize upon some particular introspective feature during each sitting. Thus, to take a single example, S gives her attention on one day quite exclusively to visualization, on another to temperature associations, on a third to the nature of the familiarity feel. This tendency reminds us of the readiness with which the observers pick up suggestions as to the probable content of the judgment consciousness (first article, 424). This emphasis upon certain phases during certain groups of tests must be fully

Perhaps we may simplify the consideration of the reaction-consciousness, if, while recognizing the truly unlooked for complexity of its structure, we attempt to outline some of the main directions in which individual variations may be expected.

I. As we have already pointed out, the attempt to restrain the expectation error may be successful or unsuccessful, nor can we predict, even in the case of a single observer, kept under constant objective conditions, that the outcome will be uniformly in favor of either tendency.

II. Some observers have a distinct emotional preference in regard to the direction of V, *i. e.*, they prefer to listen to a rising, or to a falling, variable stimulus.

III. The attention may be directed (*a*) uniformly upon the image of N, (*b*) uniformly towards V, either (*1*) directly upon V itself, or (*2*) indirectly upon V by the use of an anticipatory, changing image,<sup>1</sup> (*c*) alternately upon the image and upon V, either (*1*) by a series of rapid alterations, or (*2*) by a single shift to V near equality.

IV. The basis of the decision may be (*a*) tonal, in terms of (*1*) equality, (*2*) familiarity, (*3*) some change in V, (*b*) visual or visual-motor, (*c*) an inference in terms of the elapsed time.

V. The reaction movement may be (*a*) entirely automatic, or (*b*) an occasional source of distraction.

VI. There may be possible contrasts with preceding tests.

If, to these possible variations, we add the existing variations in the individual capacity to attend to the stimulus and to retain the memory image which our preceding tests have brought to light, as well as the variations in the sensible discrimination of our observers, we shall be prepared to find large mean variations in the numerical results and noticeable points of difference in the introspective verdicts.

#### *Observer M.*

*M* prefers to have V 'settle.' Once there was a curious illogical experience. V rose and went past equality without at any time passing through equality. The reaction was too soon; apparently expectation was excessively strong.

The usual *method of decision* is to hold the image as long as possible, then to turn the attention to V (which is, by this

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realized in the interpretation of the introspection, and not too carelessly ascribed to the objective conditions of the series in use at the time. Moreover, we think it likely that this sort of 'auto-suggestion,' if that term may be used, may lead the observer to occasional bits of faulty introspection. Thus, during one of her 'temperature days,' *S* gave the following rather doubtful case: "Image not very good. The electric lights went on just before the test: seems as if they made me feel warmer, and therefore sharpened my image."

<sup>1</sup> See under observer *Wh*, pp. 237-8.

time, near equality). The reaction occurs when V, by becoming (subjectively) more intense and "bigger," signalizes the matching-point, or when, as a result of rapid comparisons, there is an auditory or a visual 'match.' As in the tests of Parts I and II, *M*'s experience is suffused with lively visual and visual-motor imagery which is often of assistance in the decision.

The *movement of reaction* is apt to demand conscious attention.

These points are illustrated by the following introspective evidence: "Followed V down with my eyes in my imagination. Compared V with N twice at intervals, then two very quick ones when it got near." "Held image till V got near, then made two comparisons." "The series of auditory comparisons is pronounced in the form of a series of verbal judgments,—'too high,' 'too high,' 'high,' 'there.'" "V seems to swell out and get more intense at the point of equality, and this helps the judgment. This is very comforting; reminds me of the apparent spread of the æsthesiometric compass when it comes to a more sensitive area." "N on a plane by my eyes. V moved up vertically till it coincided." "N was like a caterpillar, fuzzy, yet too small in the middle, a thin thing, and very hard to remember. When V got fuzzy and thin and removed the image, I reacted." "Lost the image finally, so attended to V which recalled N at the time of the reaction." "Hate the bell; it laughs at you when you are wrong." "Frequently have to think of the button at the reaction, and this is felt to be a confusion and a bother."

#### *Observer B.*

*B* prefers to have V move down; it is easier to react then than when V moves up. In the latter case, there is more strain and nervousness, greater expectation, and a change from the usual method of judgment, much attention being given to the image.

The usual *method of decision* is to give full attention to V, the image being present, if at all, only feebly in the background. "I attend only to V, not comparing it at all with N. The image is hardly ever present in the reaction consciousness, and not usually present at all after V sounds." There may be, as we saw in Part I, an attempt to use the image in unusually difficult cases. "I react by attending to V and watching for a feeling or coloring of the tone which means equality. If this seems too difficult, I pull up the image for comparison, but it is very confusing to try to hold the image and attend to V at the same time."

*The amount of D at which V starts exercises a strong influ-*

ence upon the reaction consciousness of *B*. Very frequently the actual movement of reaction is entirely determined by this means, in other cases its approximate time only. Thus if *D* is large, expectation may be increased or a sudden caution be born. "Wasn't quite there, but felt it ought to be, perhaps from a previous estimate of *D*, so I reacted." "At wide *D*'s, I often now make a distinct effort to wait." "As soon as *V* sounds, I determine about how long it will take to get back." "Not much *D*, so I thought 'it won't take long to get there.'" "A wide *D* demands too much strain of the attention; sometimes, however, it makes me cautious and I go slower."

This observer, though very musical and generally recognizing the position of *V* at once, had several peculiar experiences with the movement of *V*. "Went up too fast at last; a sudden jump made *V* really too high at the decision." "*V* started at or near equality. At any rate, it never was equal to *N* at any time save possibly at the start." "*V* started right on *N*, I am positive." With one test ( $D = -11.2$  vib.) nine trials were necessary before *B* interpreted the conditions correctly; eight times it was reported that *V* began at *N*, or below *N*, and went lower yet. Finally *B* announced in despair "I'm all mixed up; I believe you are playing tricks with me."

*Expectation and the time factor.* The persistence with which the expectation error appeared in the case of *B*, and the rather striking fact that this error increased as *D* increased by nearly the same amount, led to the suspicion that *B* was reacting almost entirely in terms of time; that, for some reason not clearly obvious, the movement of reaction took place at practically the same time after the sounding of *V*, notwithstanding the three very different values of *D* in use.<sup>1</sup>

A series of 'puzzle-tests' (*Vexirversuche*) was accordingly planned to discover whether *B* was influenced by some 'habitual-time' tendency, analogous to an 'optimal-time' influence. In these tests variations were tried in the amount of *D* (using 0, 5.9, 9.8, 15.4 and 19.6 vib. in place of the usual values), and in the direction of *V*, which was kept at zero, or moved away from *N*, etc., etc. The regular time-interval, 10 seconds, was employed. Not until *eight* such tests had been given did *B* suspect anything unusual. She then exclaimed: "that tone went the wrong way, though I first thought it was moving up. I'm afraid you are trying to trick me." This is a very forcible illustration of the confidence which the routine of a long continued experiment will inspire.

<sup>1</sup> The alternative explanation is that the expectation error increases uniformly with increase of *D*.

So habituated was *B* to the method of procedure that eight puzzle-tests were required to shake this confidence. In several of the tests the unusual conditions produced curious illusions; thus *V* was given = *N*: *B* reacted after 3.6 seconds, giving as her report,—" *V* higher, ran down. Reaction possibly too soon, but very good. I can always tell that (!)." <sup>1</sup> These tests were continued until 25 were given. After the eighth, *B* became more cautious; at the 17th she concluded that new *rates* of change were being used. There still remained a surprising amount of confusion as to the position, but more especially as to the direction of *V*. Thus, *V* was once started 11.2 vibs. below *N* and then *lowered* at the usual rate, after nearly 15 seconds, *B* reacted when *V* was 31.8 vibs. below *N* or 20.6 vibs. below the starting-point of *V*. According to the report, " *V* at first went up; then it seemed to get more piercing, and for a long time I could n't tell which way it went. Finally it got milder and nearly like *N*, but the judgment was probably a little low."

If we compute the length of time from the sounding of *V* to the movement of reaction, we find, for the three values of *D* used in the regular tests, *i. e.*, for 8.4, 11.2 and 14.0 vibs. respectively, the following periods in seconds,—<sup>2</sup> 2.46, 3.58 and 3.18. If now we compute the corresponding values for the new *D*'s used in the puzzle-tests, we find for 5.6 and 9.8 vibs. the values 3.84 and 3.70 seconds respectively.<sup>3</sup> The average for these 5 *D*'s is  $3.35 \pm .43$  seconds. This result is confirmatory of our hypothesis of an 'habitual-time.' It may be worth while to recall here the test mentioned above in which *B* reacted to a *V* = *N* after 3.6 seconds. We conclude, from these indications, that *B* is influenced by a very strong tendency to react at about three and a half seconds after the sounding of *V*.<sup>4</sup> This

<sup>1</sup> Cf. Stern, *Veränderungsauffassung*, 94; Seashore, *Studies from the Yale Psych. Lab.*, III, 1895, 29 ff.

<sup>2</sup> These values do not correspond with those given in Table VII because they are the average for those tests only which were made before the puzzle-tests had made *B* more cautious.

<sup>3</sup> The remaining puzzle *D*'s, 15.4 and 19.6 vibs., were so unusually large that it is too much to expect that the elapsed-time influence should make itself felt without restriction. Their values, 5.02 and 5.90 seconds, are accordingly omitted.

<sup>4</sup> Despite the differences in the conditions, it seems quite probable that this influence is akin, if not identical with, Stern's 'optimal-time.' At any rate his times (3.3, 3.9, 3.7 seconds) are curiously like those obtained by us, and the statement of the law (p. 236) might equally well apply to observer *B*: "Wenn jemand einen Veränderungsreiz stetig beobachtet und den Wahrnehmungsangenblick selbst feststellen soll, so tritt um etwa vier Secunden herum eine kritische Zeit erster Ordnung ein. Die Aufmerksamkeit ist auf's höchste gesteigert, die Erwartung drängt zur Entladung, und das abschliessende Urteil wird, wenn irgend möglich, gefällt: hierbei ist dann die oh-

tendency makes itself felt almost entirely in tests in which D is plus.<sup>1</sup> Very likely this is correlated with the preference above mentioned for a descending variable because of the ease of judgment then. The 'ease,' we think, is due to the control exercised by this unconscious 'time-release' factor.

*Observer S.*

One of the most prominent features in *S*'s introspection is the *identification of N* by the use of several different categories. This seems to be partly a relic of the procedure with right and wrong cases<sup>2</sup> (each N being, as soon as heard, compared with the N of the preceding test), and partly a desire to gain a feeling of order and security in the work by arranging a schema of the standards in use. *S* thought at first that there were six or seven, later three or four standards. These appeal to her as differing from each other not only auditorily, but in temperature<sup>3</sup> and size, and occasionally in other respects, personal characteristics, etc. "N places itself in my scale auditorily, visually and in regard to its temperature, and remains placed there throughout the test. The warmest N is comfortably warm, more than lukewarm; the coldest is just like pleasantly cool water, this being the lowest tone used. Some tones are masculine, others (generally the higher ones) feminine." "Could not place this N in my series, and this bothered me as it gives me confidence to get N put readily into my scheme of identification."

Though, as might be expected, this process of identification was not always successful, the assignment was more often than not correct. There is no question but that the contribution supplied by the other sense departments is the essential basis of this process. *S* knows that a given N is a cool one before she knows that it is (relatively) low in pitch. Here we have a striking illustration of an unusual and unlooked-for means for the recognition of the impressions of one sense department in terms of another. It seems quite unreasonable, logically, but not, after all, so unreasonable psychologically, for, as we have already pointed out, *S* has a poor auditory discrimination, but a very strong affective reaction to tones. It is this affective supplement which catches the attention, therefore, and which gives individuality to the various standards.

The same prominence of *visual factors* which characterized *S*'s experiences previously appeared here again with even

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jective Grösse, welche die Veränderung in jener Zeit erlangt hat, innerhalb weiter Grenzen irrelevant."

<sup>1</sup> The figures just given all refer to a descending variable tone.

<sup>2</sup> Cf. especially 439 (6) of the first article.

<sup>3</sup> Cf. first article, 420, 428, 437, 451.

greater distinctness than before. We have said that *N* seemed to have a certain visual size and place. *V* invariably evokes a still more pronounced visualization, usually described as "a smoky, gray round thing moving up or down and making a rope as it goes. " "I watch the moving end or knob. *N* is a similar round stationary thing at the left of *V*. I seem to stay on the *V* side and look towards the image on the left. When *V* goes down it drops vertically, but when it goes up, it always moves obliquely out away from me at an angle of about 45 degrees." The visual phenomena thus described are not so active as determining agents in the reaction consciousness as those which serve to identify *N*. Here they are, as *S* puts it, rather the expression of the auditory relations between *V* and *N*.

The actual *decision* is usually either (1) the result of a series of auditory comparisons (the attention being for the most part on *N*, and jumping over to the image for a moment), or (2) the result of some modification of *V*. It is noticeable that the latter type of decision became more prominent as the work progressed, less and less importance being attached to the image. This is entirely in accordance with what we have already had occasion to mention so frequently,—that the process of image-comparison is used in cases of difficulty when the direct method is, for any reason, not available. The modification of *V* may be an auditory swelling, as in the case of the observer *M*, but oftener it takes the form of some organic or affective response. "Reaction based this time upon a certain individuality which appeared in one place in *V*,—something auditory perhaps." "When I reacted, *V* 'stood out,' was 'my tone.' "

"At times, at the moment of reaction I see a whitish convex thing which appeals to me as something graspable; the rest of the tone is not thus graspable." (3) A third, somewhat less frequent, basis for the decision is the experience of a sudden *bodily glow or warmth*. We may suppose that this is a constituent of the organic reaction which forms the essence of the 'mood of familiarity' or 'quality of knownness' for this observer, but like many constituents which enter into rapid and complex mental processes, its presence is only distinctly made out in occasional introspections when the conditions favor analysis. It is credible, too, that *S*, who experiences strong affectively colored associations of temperature with tones, should, on that very account, be the observer to analyze out this particular feature of the familiarity feel most successfully. On the other hand, *S* herself says that the warmth which comes with recognition is quite distinct from that which is ascribed to tones. The former is experienced in other cases than in the recognition of tones; it comes, for example, when the point of an argument in a lecture becomes suddenly clear.

The similarity of this case to the recognitory consciousness in our tests is not very difficult to perceive.

There remains to be mentioned, in the case of *S*, a strong preference for a rising *V*. "It is pleasant to have *V* grow strong and big, depressing to feel it sink." One may accordingly explain the overestimation error as due to an unconscious prolongation of the pleasurable movement of rising variables, or to an unconscious premature checking of the depressing movement of descending variables.

It has already been mentioned that *S*, owing to a poor sensible discrimination, had, at times, difficulty in perceiving the *position of V* at once, especially with the smallest *D*. Frequently the actual movement of the tone supplied the desired knowledge. In nine out of 36 tests, however, *S* carried out the tests completely and then reported that *V* moved in the opposite direction to that actually executed. These tests were given again (being interspersed in a regular series) until correctly interpreted. A single repetition was sufficient in six cases, three or four in the others. In five cases, *D* was 8.4 vibs., in two cases, 11.2, in two cases, 14.0. These rather anomalous results raise an interesting point. How are we to interpret the quantitative value of *S*'s tests, especially her estimate of equality, when, to take one example, *V* was descending from 14.0 vibs., and *S* reported: "V went up, a good swelling tone; judgment of recognition?" A more hopeless confusion of the objective conditions could scarcely be imagined in view of the long practice *S* had had. We are still, however, ready to assert that the reaction might quite well have indicated a real recognition of the merging of a difference into an equality. The results of *B*'s puzzle-tests show how easily the direction of a movement of a continuously changing tone may be mistaken. It has, again, often been asserted, and our previous results have everywhere confirmed the assertion, that difference is more readily noted than the direction of the difference. Finally, we have shown how dependent *S* often is upon supplementary contributions from other modalities for her perception of tonal relations. The introspective evidence points clearly to the influence of these contributions in producing many of the confusions. If a tone seems to be 'swelling,' or is visualized in the wrong position, this is enough to override the direct perception of its auditory relations. *S* herself says: "I think I am too much influenced at times by my visualizations." We may conclude, then, that in the case of *S*, some one of a number of extraneous factors causes a misapprehension of the proper place of *V*; this influence is so strong that, coupled with the general difficulty of perceiving the direction, it overrides the objective conditions. However, *S*

knows that *V* is different from *N*, and makes a satisfactory reaction when it reaches equality.

*S* noted occasionally a short but distinct interval between the formation of the decision and the pressing of the reaction key.

*Observer Wh.*

The method of decision in the case of *Wh*, although it changed as the tests progressed, was throughout much more exclusively auditory than that of the other observers. At first there was a series of auditory comparisons. But very soon comparison was given up, although the auditory image was still maintained by effort during the time-interval, and, as long as possible during the sounding of *V*.<sup>1</sup>

The common method pursued by *Wh* is thus that in which the judgment is auditory-motor (or auditory), the attention being held upon the image with all possible persistence, not alternating between the image and *N*, but merely waiting for coincidence. When, however, *D* is large, there are what *Wh* calls occasional 'looks' at *V* (not comparisons or 'balancings,' but brief shifts of the attention).<sup>2</sup> "I image the ideal tone as soon as *V* sounds and keep this ideal in mind somehow, but toward the end my attention 'flops over' to *V*, and I come down with it to the place (*i. e.*, *N*) from which I had jumped to it. The 'flopping over' has a distinct motor feel about it." "Once I tried so hard to think the image that I didn't attend to *V* at all, so that the decision was very uncertain. Found no equality point at all." "I still hold to the image, but it seems a place in space to get to quite as much as an auditory quality, for the tonal image is not distinctly present."

The second chief method used by *Wh* is a peculiar one, for the attention is not directly upon either the image or *V*; in fact, there cannot be said to be any image in use, in so far as we mean by the image a representation of *N*. As *V* moves along by a series of slumps or slurs (descending or ascending *V* respectively), *Wh* at each stage imagines what the next stage is to be. Perhaps an introspective report will make this clearer. "I attend in a way to *V*, yet I am, so to speak, go-

<sup>1</sup> Naturally, as we have seen in the case of the other observers, when *V* gets so near *N* that it becomes a source of confusion to the image, the attention, compelled by the insistence of the sounding tone in contrast to the natural feebleness of the image, is very apt to go over to the variable and be held there until the reaction. As the tests continued, the spatial characteristics of the image became of more importance, and the image (we use the term for whatever is held in consciousness to represent *N*) lost much of its auditory nature.

<sup>2</sup> In distinction, for example, from the procedure of *M* in passing a series of verbal judgments.

ing ahead of it auditorily and coaxing it along; mentally hearing it take its course from difference to equality just in advance of the tone itself. When V has completed the path I thus made for it, I react."

Finally, *Wh* uses occasionally the method already mentioned of relying solely upon some change in the (subjective) nature of V or upon the appearance of some familiarity feel. This form of decision is not used by this observer save when other means fail. "Distinct swelling of V at the right place." "No image at V, so attended to V to see when it got familiar. At a certain area it aroused a 'familiarity tag' and the reaction. I'm not at all sure of this sort, rather have some idea of the place of N in mind all the time." "When D is very large, I sometimes lose my image-place entirely and have to go by the familiarity feel."

The amount of *D* did not exercise over *Wh* so great an influence as upon the other observers (especially *B*). Occasionally, of course, a wide *D* increased the tendency to premature reaction: "Big *D*; had a strong expectation which made the rate of V surprisingly slow." More frequently quite the reverse effect appears: "Pleased with wide *D*, for then there is plenty of time. I can be calm and make the reaction coolly."

The influence of *D* as a determinant of the reaction by a computation of the time necessary (*i. e.*, quite apart from its influence upon expectation) seems not very strong with *Wh*. While cases appear like those of observer *B*, there are many others in which the estimate of the size of *D*, instead of determining the moment of the reaction, is itself revised by the influence of the other factors in the judgment consciousness. "I thought the *D* was small, but the tone was some time in reaching equality, so (as I know this means a wide *D*) concluded I was mistaken in my first thought."

The movement of reaction "seems now to be fixed, united with *N*, in such a way that whenever *V* reaches *N*, the reaction 'goes off,' usually quite automatically." "Just before *V* gets to equality, I put my finger on the key, my arm muscles set for the movement, and feel in general a very pleasant anticipation of making the reaction. It is a sort of 'hitting the nail on the head' feeling, or like chopping a running rope at some fixed point."

### Series 2.

This series consists of 36 tests for each observer, identical with those of Series 1, save that the time-interval is 40 seconds.

The quantitative results are extremely irregular, so much so that it is useless to present them in tabular form for extended

comparison with those of the other series. It will suffice to point out, for example, that in five out of 24 cases the expectation error disappears, that there is, in the remaining cases, no sign of any relation between this error and the size of D, that the mean variations (except for *S*) are uniformly larger than before, that the estimation value of *N* is not constant in sign for any observer (save for *B* who underestimates with all three values of D).

The cause of this rather unsatisfactory outcome from the quantitative point of view is not far to seek. It is due to the fact that, to the natural difficulties of the continuous change method which we have just discussed in detail, there is added the difficulty of the long time-interval.

The *qualitative reports* are quite as irregular and quite as difficult to put into tabular form as the quantitative. To begin with, the observers differ very much in their use of the auditory image. Thus, in 36 tests, *M* reported 25 cases in which the image was present in the decision (in 22 of them after having persisted throughout the interval), three in which it was not present, and eight unclassified; *B*, on the contrary, reported only 10 cases with the image and 13 without it, while the remaining 13, in which this point was not explicitly settled, probably belong to the latter type. *S* makes use of her visual images quite frequently; *Wh* reacted with an auditory image 16 times, without any 13 times.

Despite these variations, the following general propositions may be laid down. (1) Owing to the long practice now attained, the auditory image can be held somewhat better than during Series 3 of Part 2. (2) The presence of the image (even if the auditory core is lacking) affords greater assurance in the reaction. (3) It is helpful to have the image persist in some form until *V* starts, even if it does not enter consciousness again; to have in mind a definite place for *N* when *V* begins, because recourse is thus had to a decision based on the amount of *D*. (4) It is, however, possible to make an objectively satisfactory reaction when the image has been permanently lost before *V* sounds. Such reactions are most frequent for observers *B* and *Wh*. *B* finds them subjectively satisfactory, *Wh* much less so. The actual basis of the decision of this type varies. If the recognition seems rather hopeless, the observer is apt to catch at the slightest indication of equality. "Image entirely gone, yet knew *V* started below. This time, however, I had neither a tone nor a place in mind for *V* to reach. So I watched *V* to get a familiarity, but reaction was really largely due to a feeling that *V* had gone on long enough" (*Wh*). "The familiarity feel seems to be something bodily which comes on gradually and finally engulfs me" (*Wh*). "Sometimes the visualized

note becomes a warmer gray at the moment of decision" (*S*). "V seems to 'splay' out or extend itself horizontally when it gets to the proper level" (*Wh*). "Just watched V and waited for myself to react, automatically, as it were" (*Wh*).

In Series 1, we saw that *S* and *B* had occasionally anomalous tests in which the *position and the direction of movement of V* were not correctly apprehended. The long time-interval of Series 2 magnifies this difficulty, so that we find five such cases accredited to *M*, nine to *B*, 27 to *S*,<sup>1</sup> and four to *Wh*. Now it is worth while to examine these cases in more detail. For the sake of simplicity, let us class them according to the apparent starting point of *V*. The resulting distribution is, then, as follows: started at equality and went up, 3; started at equality and went down, 2; started above, 2; started below, 17; miscellaneous movements<sup>2</sup> and totally unrecognized cases, 19. The pertinent feature of this distribution is the predominance of the cases in which *V* seems to start from below. Taken with the prevalence of comments by the observers upon the ease with which the position of *V* is recognized when it does start from below, we find confirmation of the principle upon which we insisted in Part I, viz.: that, for most observers, there is a tendency to sharp the image in the case of a long time interval.<sup>3</sup> Whether the auditory image is actually present when *V*

<sup>1</sup> One is, perhaps, warranted in saying that for *S*, discrimination by the continuous change method is practically impossible with this time-interval. *S* was tested roughly for S. D. by the aid of the piano, two notes being struck one second apart and the judgments 'equal,' 'higher' or 'lower' being required. The results for musical intervals from unison to the octave gave 94 per cent. right cases, the wrong cases being entirely confined to a single interval, the major second. Incidentally it appeared that *S* was liable to mistake a difference of intensity for a difference of pitch. This tendency was further investigated by special tests and the result confirmed; it was also found that a variation in the intensity of the stimuli would influence the estimation of the relative size of intervals, and that minor intervals were usually overestimated. These results simply bear out our general contention that *S* is very unmusical and that, in the more difficult series of our experiments, the task imposed was beyond *S*'s capacity for *sensible* discrimination.

<sup>2</sup> This class includes a variety of combinations of which the following are examples:—"V appeared equal. Don't know which way it moved."—"V seemed to start below and yet to go down. I was determined to have it go up, and tried to make it do so in vain." "Began slightly lower, surely, but didn't approach N. Stayed on same pitch or wabbled around it." [In this case  $D = +14.0$  vib., really. A striking illustration of the influence of expectation with observer *B*. The erroneous preliminary estimate of the position of *V* sufficed to suppress completely the perception of the actual movement of the tone. Very likely the "wabble" was due to an actual alteration of attention between the expected and the given direction of movement.]

<sup>3</sup> See first article 422 (2 b), 426, note 1, 432 (5 a) and note 2.

starts or not, the fact that its pitch (and also, as a rule, the various organic sets and other associative supplementings) has been gradually raised in the endeavor to maintain it as vividly and clearly as possible, brings it about that the 'level' representing the place of the standard has been altered at V. Putting the matter in another way, the unconscious, gradual sharpening of the image during, say, 30 seconds, will affect the identification of V at the 40th second, even if the auditory image has ceased to be consciously present. "Image absolutely gone, but V immediately aroused a verbal 'high,' and was felt to be *so* high. I knew at once approximately *where* the image must have been, though 'I did n't hear the image sound again'" (*Wh*).

In connection with the gradual fading of the image and the difficulty of maintaining it in serviceable condition for the 40 seconds interval, there should be noted a very frequently reported phenomenon, that of the *arbitrary alteration or displacement of the auditory image*.<sup>1</sup> Apparently the auditory image is not always the determinative feature of the complex which stands for N during the interval. The observer sometimes controls the tonal image by reference to some other material as a basis. This scrutiny of the image is clearly illustrated in the ensuing quotations. "Two images during the interval. Knew the higher was the correct one." "Put this image too far down, misjudged it, so when it insisted on raising itself, I had to let it do so." "Lost image for awhile; then two came back, distinct from each other, auditorily and spatially. The real one was the upper one, but it had a tendency to fall down into the lower one, so that I had to keep pushing it up. It was a regular nightmare, like emptying lakes with a thimble" (*M*). "Changed my image during interval. Thought it too high and voluntarily put it down" (*B*).

Finally, there is to be mentioned the growing ability to *recognize and identify the three standards*. We see no reason to correlate this specifically with the use of the long time-interval; it may be attributed merely to the growth of special practice. *Wh*, possibly because his pre-knowledge of the actual conditions satisfied his curiosity on the point, did not develop any system of classification. *S* concluded that there were three standards or three groups of standards, perhaps two low, two high, and one in the middle. The lower standards were cold and colorless. *S* could frequently identify the standard by means of these associative tags, saying—"That's a cold one," "That's the warmest one," etc. This process made the test more easy of completion: "Not a good reaction because I

<sup>1</sup> Something of the sort was noted in Part I, e. g., the double images of *F* and *Wh*, 430, 5a, 432, 5a.

did n't get N well identified in my scheme of standards." *M*, quite similarly, came to suppose that there were three groups of standards, with about three tones in each region. She could also frequently assign the standard to these groups correctly, *e. g.*, "That was one of the middle ones, neither high nor low; a very ordinary tone, hard to remember and discriminate. These middle tones seem more spread out, less graspable." "Sometimes the sounding of N clears up a sort of confusion which begins at the 'ready' signal [anxiety or curiosity about N]. It is like a ray of light coming through smoke. Even then, there is a fraction of an instant between hearing N as *a tone* and knowing it as *this tone*, a high one, low one, etc. This identification is quite pleasant. I often feel like 'shaking hands' with N, and saying 'Hullo, there.'"

Observer *B*, it is perhaps not too much to say, actually came to have an absolute pitch memory for the three standards. We say "perhaps," because the identification was of a peculiar sort. *B* did not say that a given standard was the high, middle or low one, although she thought there were three (or four) standards, but that a given tone was the one used in this or that test, usually recognizing the identity of standards in successive tests. The accuracy and the positiveness of *B*'s assertions are remarkable because often fully five minutes elapsed between the tests, and the report of the introspection sufficed completely to distract the attention from the auditory experience. Once *B* recognized V (instead of N, curiously) as identical with the V of the preceding test, but could not place it with certainty in relation to its own N. In another instance, the standard given in the eleventh test was positively identified as that given in the first test. *B* herself thinks this capacity is due to the fact that since the identification is not the object of the experiment, she is free from expectation and from the feelings of confusion incident to the task of reaction. But it should also be remembered that the identification calls for the discrimination of discrete tones only, that the three standards are 14 vibs. apart, and that there has been long practice with these same three standards. *B*'s identification of a given tone with a certain other previously experienced may still be, at bottom, a discrimination based upon an acquired absolute pitch memory of a moderate degree.<sup>1</sup>

A minor effect of the long time-interval is to lessen the *assurance*. "After V is 'placed' (higher or lower), I like to watch its movement for a moment to get added security." "If I have a bias for a given position of V, and it turns out other-

<sup>1</sup> Cf. M. Meyer, *Psych. Rev.*, VI, 1899, 514.

wise, my confidence in the outcome of the whole test is shaken" (*Wh*).

*Series 3.*

This series is a repetition of Series 1, but by the method of procedure with knowledge. The subjects knew that there were three standards, three D's, and they were told the direction, but not the amount, of the D for each test. The object was, of course, to see what effect, especially upon the expectation error, would result from the previous knowledge of the direction of V.

*Quantitative Results.*

TABLE VIII.  
to Second Interval. Procedure with Knowledge.

Obs.	D	V <sub>o</sub> III N	m. v.	V <sub>u</sub> III N	m. v.	Aver. Limit of Error.	Estimation Value of N.
<i>M</i>	8.4	3.08	0.86	-2.91	1.34	2.99	0.08
	11.2	5.35	1.29	-4.37	1.15	4.87	0.05
	14.0	6.30	1.20	-6.55	0.90	6.44	-0.14
<i>B</i>	8.4	-0.11	0.64	-1.46	0.90	0.78	-0.78
	11.2	3.02	1.43	-2.10	1.70	2.58	0.48
	14.0	3.58	2.10	-3.83	2.16	3.72	-0.14
<i>S</i>	8.4	0.86	1.45	1.23	2.94	0.71	0.71
	11.2	2.57	2.27	-2.01	1.60	2.29	0.28
	14.0	4.14	2.46	-1.45	2.01	2.80	0.92
<i>Wh</i>	8.4	-0.39	1.20	0.33	1.23	0.36	-0.06
	11.2	-0.11	1.09	-1.45	0.75	0.78	-0.78
	14.0	-0.08	2.10	-3.11	2.60	1.60	-1.60

Table VIII shows the quantitative results of Series 3. In comparing it with Table VII, one must bear in mind that the tests are relatively few in number, that the results are influenced by the increasing amount of practice, and that the procedure with knowledge is not, after all, very different from that without knowledge, for the difference lies mainly in the acquaintance with the coming position of V. Now, with the short time-interval, as we have pointed out, the observers, with the exception of *S*, had practically no difficulty in recognizing at once the position of V. In view of these facts, it is not surprising that, on the one hand, certain minor differences are observable, but that, on the other hand, the general features of Table VII are repeated in Table VIII. We are, indeed, almost repeating verbatim our résumé of Table VII when we sum up Table VIII by saying:

(1) With one exception for *B*, one exception for *S* and four for *Wh*, the 24 values indicate an error of expectation.

(2) For all observers the expectation error increases with increase of D.

(3) The mean variations are large, though, as a rule, less than in Table VII.

(4) *Wh* constantly underestimates, *S* constantly overestimates, *N*.

(5) All of the observers have a lower average value for the estimation of *N*, *i. e.*, exhibit a more accurate recognition.

The reduction of the mean variations and the increased accuracy of recognition are, we think, due to the simple growth of practice, not to the procedure with knowledge. The increase of expectation in the case of *M* is not easily explained. Possibly the procedure with knowledge engendered some carelessness, but, as will be shown presently, the contrary effect is given by other observers.

#### *Qualitative Results.*

The *general effect* of the knowledge of the coming position of *V* is simply, as reported by *M*, *B* and *S*, to give a feeling of security, to do away with the momentary perplexity or attentive curiosity as to whether *V* would be easily placed.<sup>1</sup> The attention, toward the end of the interval, can be kept more completely upon the image. There is greater quiet and calmness throughout the test.

Curiously enough, *V* does not always seem to start from the direction announced. *M* had one instance, *B* three instances and *S* two, in which, after 'higher' had been designated, *V* started from below or at equality. In all six cases the smallest difference was in use.

A second effect, reported by *M*, *S* and *Wh*, is the presence of an *anticipatory image of V*. *M* had this experience but once: "While my image was going on, I heard also what was to be *V*. I thought 'well, that's my imagination,' and tried to attend only to *N*. Behold the real *V* matched this secondary image perfectly." *S*, who says she never hears a tone in any test which is not visualized as a spot or line at a definite point in space, and that the procedure with knowledge makes this effect clearer and more intense, very naturally visualizes the expected *V*, though frequently she also hears it. "In many tests, as soon as the operator says 'plus' or 'minus,' I project two spots, one in the middle for *N*, one above or below it for *V*." "During the interval kept going visually from *N* to a lower place, but heard only *N*." "This time had both auditory and visual image of the coming *V*. I anticipate usually in about the same

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<sup>1</sup>*Wh*, perhaps because of never feeling this anxiety very keenly, found little difference in this regard.

place."<sup>1</sup> In the case of *Wh* the anticipatory image is far more prominent and largely auditory. "There is a strong tendency to ideate V. I actually hear another tone lower or higher than N. This I usually try to repress in part by attending sharply to the image of N." This sentence is an indication of an interesting effect of the knowledge method. It looks as if, for some observers, the knowledge of the position to be taken by V might be more distracting than helpful. It frees the observer's mind from anxiety as to 'placing' V, but it thrusts upon consciousness an obsession which is still more bothersome. *S* voices this idea when she says: "I think that the expectation of a 'plus' V raised the image of N both visually and auditorily."

Series 3 also gives us further data concerning the *method of decision*. The points brought out are to be ascribed to the influence of continued practice rather than to the method with knowledge itself. In general, each observer's report has become more settled and uniform. There are a larger percentage of tests in which the same method is described. At the same time, the differences between individual observers are more clearly defined. Thus we find that *M* never uses the amount of D as a basis for calculating the time of the reaction, and that, with her, auditory-verbal judgments are very frequent, *e. g.*, "Ah!" "There!" "That's it," "Now," etc., etc. We find that *Wh* has settled down to a single method which is used constantly save when some accidental variation (*e. g.*, the anticipatory image just mentioned) interrupts its course. This method (practically the first main method of this observer in Series 1) is to attend with all diligence to the auditory image throughout the interval. When V begins, the image stands out sharply in contrast, but as V continues the image rapidly dies out, so that when V nears equality, the attention goes over to V and is kept there till the reaction. In the case of *B*, we find that practice has induced more caution; she attends more sharply to the image during the interval (though still to V when it comes) and attempts voluntarily to inhibit premature reactions, especially with a large D. On this account the expectation is largely reduced. Indeed, it disappears with the smallest 'plus' D.

It is of interest to note that, in contrast especially to *M*, *B* never thinks of V as fusing with the image. It could n't "because the image is in the head, the tone outside." "I never thought that the tone could have anything to do with the image." The reaction is entirely automatic: "goes off when

<sup>1</sup> When we also read that in the majority of tests, D is found to be "surprisingly small," we are led to surmise that her anticipated position is too far away from the standard, and that this process may be a source of a constant error in the reactions, though the quantitative results cannot be said to give definite indications of such an influence.

familiarity is reached." *B* is very much bothered by periods of loudness or swelling in *V*; these are noted, however, only with a descending *V*. During these periods she is unable to react or to tell anything about the place or movement of *V*.<sup>1</sup>

*S* continues to make occasional reactions based upon a bodily glow, significant of familiarity. At other times, there is a "sense of ownership:" That part of *V* which is like the image is 'mine,' the rest of it is 'foreign.'" There are usually two distinct tendencies to react before the finally successful tendency. These tendencies appear in a sort of rhythmic sequence, and are so related that it would be impossible to react during the interval between them. All this suggests an optimal-time factor. *S* does not, however, make reactions based upon the lapse of time as determined by the size of *D*. She may, like *Wh*, estimate the size of *D* erroneously, but usually neglects this estimate if *V* does not reach equality at the expected time.

#### *Series 4.*

Series 4 comprises 36 tests with a time-interval of 10 seconds, the image being eliminated, so far as possible, by distraction set up by odors. This series is, therefore, comparable to Series 1 of this Part and to Series 4 of Part II.<sup>2</sup>

#### *The effects of distraction.*

(1) *On the image.* The results of distraction, are, in general, similar to those recorded in Part II, although the continuous change method produces some individual variations not observed before. These variations, which are correlated with the individual variations in the method of decision, are all due, at bottom, to the continual sounding of *V*. To be more explicit: in Part II distraction was employed with discrete tones; if distraction was complete during the interval, the judgment was usually made without the appearance of the image. In the present series, from six to ten seconds intervene after the cessation of the distraction before the time for the decision arrives. During this period the image may very well assert itself, even if it has been successfully repressed during the time-interval proper. The possibility of this recall has been foreshadowed by our previous citations of cases in which the sounding of *V* "revived" the image, or caused it to "stand out in contrast."

In Table IX data are supplied showing the outcome of distraction as regards this point of the suppression of the image.

<sup>1</sup>This phenomenon is entirely subjective. *S* had a few such instances with an ascending *V*. *Wh* was never bothered. The uneven movement in pitch, previously discussed, is quite independent of this intensive variation.

<sup>2</sup>See first article, 455-6, for further details.

As in Table VI, four possible types of distraction are recognized: viz., (a), the total disappearance of the image, (b), momentary reappearance once (or twice) during the ten seconds without being present thereafter, (c), a similar momentary reappearance during the interval with a persistence into V, or another reappearance during V, and (d) an appearance at the first sounding of V or during its course. The fifth column gives the sum of the first two columns.

TABLE IX.  
*The effect of Distraction. (36 cases for each observer.)*

Obs.	None	Momentarily in Interval	In Interval and at V	At or after V only	Not at V
<i>M</i>	17	10	4	5	27
<i>B</i>	27	9	0	0	36
<i>S</i>	19	3	2	12	22
<i>Wh</i>	17	5	10	4	22
Total.	80	27	16	21	107

From this Table, in comparison with Table VI of Part II, the tendencies just discussed are easily apparent: thus *Wh*, just as before, attained complete distraction in 17 cases, but, whereas before there were 17 instances of type *b*, and *none* of type *c*, the latter type is now twice as frequent as the former, while type *d* is doubled. Again, observer *S*, although reporting more instances of complete distraction, has twice as many of type *d*. All these cases show clearly this tendency of the auditory image to make its appearance at or during V under the conditions of the continuous change method.

But this tendency may be modified or entirely suppressed in the case of an observer who is not in the habit of using the image as a basis for the reaction. Thus the striking fact, that, for *B*, the image was never present at all during V, is explicable because, in the first place, *B* probably never attends as keenly to the image as do the other observers; and, in the second place, odors readily attract her attention, so that a high degree of distraction is easily produced during the time-interval. This is evinced by the 75% of cases under type *a*. And, finally, *B* does not, as a rule, make use of the image in the decision. Hence when the image is absent at the beginning of V, *B* naturally adopts the method of decision in which the attention is directed entirely to V and the reaction conditioned upon the arousal of some symbol of familiarity.

*M* exhibits neither the tendency of *S* and *Wh*, nor the contrary one of *B*, but the figures in her case closely correspond to those of Table VI. It should be borne in mind that when

the image reappears, especially during the time-interval, it is present only in the vaguest form and with a very short duration. Thus *M* reports: "Image very faintly, almost unconsciously, present. Felt it was near me without being there." "Half remembered *N* during interval." A typical case for *B* is: "Complete distraction. Odor bergamot; many associations, stories of bergamot and lavender, old New England people, etc." Her type *b* is thus illustrated: "Image back faintly once near the beginning of the time-interval, but at *V* had no idea where he was or where the reaction should come." *S*'s prominent type *d* is given as follows: "Faint auditory image appeared half-way through *V* and was used in reaction." "Image appeared very quickly after *V* started in response to voluntary effort to haul it up." *Wh* has, as a rule, either complete distraction (which he secures by vigorous attention to the odor, "seeking for its name, encouraging associations, testing its intensity for each nostril, etc.") or distraction of the third type. "Image back a moment at about the seventh second, and also at *V* so that it served as a standard, though I could not keep it throughout as I wished." These two types are very clear, and are correlated, as will be shown below, with two distinct methods of decision.

(2) *On the identification of N.* Observers *B* and *S*, who had both developed the process of identifying the standard to a high degree, find that the direction of the attention to the odor immediately upon the cessation of *N*, interferes with this process, and, to a certain extent, renders the entire test more difficult. "I have come now to attend very closely to *N* when it sounds. I find this necessary with distraction" (*B*). "Distraction makes the experiment harder. Don't have time to place *N* in my scale" (*S*).

(3) *On the 'placing' of V.* Just as the attention to the odor at the beginning of the interval wrenches the attention from *N* before it is entirely apperceived, so the attention to the odor at the end of the interval is so well established that *V* comes as something foreign to the consciousness,<sup>1</sup> a shift which consumes a noticeable time. The gap is estimated by the observers at from a quarter of a second to a second and a half. This gap plays a distinct part in the quantitative results as will appear in Table X. Another and more immediate consequence is that the place of *V* is often known, not directly, but by the observation of its movement. "V sounded one second before I knew what I was doing." "Have to gather yourself up to attend to *V*." "Did n't get *V*'s direction till I watched it move" (*M*). "Slight gap between attention to odor and apprehension of tone, but usually place *V* after that, at once" (*B*). "Takes a short

<sup>1</sup> Cf. first article, 455.

time to get adjusted to V which I never recognize immediately." "Took one second to know V was going up and then got it from the movement. Took a long time to forget the smell" (*S*). "Complete distraction. Took one and one-half seconds to know V" (*Wh*).

(4) *On the method of decision.* In our discussion of the effects of distraction upon the image, we have already foreshadowed its effects upon the method of decision. In general, we may say that complete distraction compels those observers who formerly made use of the image to resort to the other chief method, that of attending to V and reacting to familiarity of some sort. Now, since *B* naturally used this method, her introspection may be dismissed herewith, as bringing out nothing essentially new. *M* shows the correlation clearly; with complete distraction she attends to V "until N seems to be sounding again." "Fine distraction; no image; matched where N was." If, on the other hand, the image is clearly present during V, it becomes the object of attention and is used as a standard. There is, too, a sort of intermediate type. "If I have the image at all during the interval, I am half-way ready for V."

*Wh*, who uniformly used the image whenever possible, presented, as we saw, two main types of distraction, viz: *a* and *c*. His method of decision consequently was of two distinct sorts, much akin to those of *M*, but even more clearly demarcated, as the following instances will show. Type *a*: "Complete distraction, V placed by its own movement; no idea of pitch or place of N, reaction absolute guess-work, touched off by the merest trace of resemblance." "Knew V at once as lower, but had no idea *how much* lower."<sup>1</sup> "Reaction came as a sort of despair." Type *c*: "If the image has been present at any moment during the time-interval, it is more apt to emerge during V. Even if not, it at any rate seems to 'fix' N, so that the reaction is much more easily and confidently made." "Image back a moment about the middle of the interval and also at V, so that it gave a basis for the reaction." Between these two main types there are, as with observer *M*, intermediate varieties which are interesting from the light they throw upon the others; *e. g.*, "Distraction good, though possibly the image was on the verge of reappearance once. Judgment uncertain, but less so than in some. Had general idea (auditory-verbal) 'wide D,' but no concrete idea as to *how wide* this one was." Here one may

<sup>1</sup>The same report is often given by *B*. These cases are instructive when compared to similar instances in the discrete experiments when V was cognized as absolutely 'high' or 'low,' but not as 'higher' or 'lower' than any standard. Note that there such knowledge sufficed to produce a successful judgment; here it is of no avail in determining a successful reaction, for the *how much* is all important.

suppose that the faint re-establishment of *N* was sufficient to arouse the general idea "wide *D*," but not sufficient to relate *N* and *V* more definitely. The assurance is likewise of an intermediate grade.

When distraction is complete, *S* often characterizes her reaction as "wild," "vague," "quite in the air," etc. In such cases the reaction is determined by some vague feeling of familiarity: "*V* stands out visually." But frequently, perhaps in the majority of these cases, *S* has a visual-spatial idea of the place of *V* in relation to *N*; *e.g.*, "Image not present at all, but I had a general estimation: let *V* go about so far,—half way down or to the middle of the screen where *N* is put."<sup>1</sup> "Reacted to vague idea of place." "Have a vague feeling of the amount of *D*." Least frequent is a type of decision similar to that of *M*. "Try to see a clue to the image in each 'tone' of *V*." This is, of course, in contrast to her general method of keeping the image in attention and trying to find something like it in *V*. Occasionally *S* entirely fails to react, but simply exclaims: "I don't know anything about it."

(5) *On the assurance.* Distraction, like a long time-interval, lessens assurance.<sup>2</sup> This is especially true for observers *M* and *Wh.* *B*, who makes little use of the image generally, is also less certain under distraction. *Wh.* is the more uncertain, the greater the distraction, yet "none of these results are quite as satisfactory as if there was no odor at all to distract." "The image in the continuous change experiments is so useful to me that any weakening of it makes the decision less assured." Very many of the reactions which seem most doubtful to the observer are relatively accurate objectively; in other words, assurance and accuracy do not vary in common. Good reactions are made, not only when the observer pronounces them definitely bad, but also when the observer is "utterly at sea" and knows nothing about the reaction. The explanation of this will appear in a moment.

(6) *On the quantitative results.* In Table X will be found the quantitative results for Series 4. The effects of distraction, as we have already intimated, vary with the observer.

Let us first take the results for observer *B*, who, it will be remembered, was relatively little affected by distraction because her normal method of decision involved attention to *V* with little or no attempt to relate it definitely with the image. Her results in the present Table are practically identical with those

<sup>1</sup> To make this intelligible, it should be explained that *S* habitually sat with her right ear toward the source of sound, and hence facing the cardboard screen (first article, 417) upon which she projected her visualizations of the tones.

<sup>2</sup> Cf. first article, 456.

TABLE X.  
10 Seconds Interval, with Distraction.

Obs.	D	V <sub>o</sub> III N	m. v.	V <sub>u</sub> III N	m. v.	Aver. Limit of Error.	Estimation Value of N.
<i>M</i>	8.4	—0.35	2.24	—2.06	1.37	1.20	—1.20
	11.2	0.64	1.37	—0.37	1.12	0.50	0.14
	14.0	1.29	3.02	—4.28	2.71	2.79	—1.50
<i>B</i>	8.4	1.90	1.23	—1.93	1.85	1.92	—0.02
	11.2	3.53	1.48	—3.33	0.53	3.43	0.10
	14.0	4.48	1.65	—6.41	0.87	5.45	—0.97
<i>S</i>	8.4	—2.44	1.20	5.88	1.76	4.16	1.72
	11.2	—3.36	1.26	3.05	2.01	3.20	—0.16
	14.0	0.53	0.73	0.28	2.69	0.40	0.13
<i>Wh</i>	8.4	—1.88	1.40	2.43	2.27	2.16	0.28
	11.2	0.28	0.92	—0.22	1.76	0.25	0.03
	14.0	0.14	1.06	0.20	2.80	0.17	0.17

of Table VII, save that the size of the expectation error is slightly reduced.<sup>1</sup> This general reduction may be due either (1) to a slight caution, born of practice, or (2) to the slight 'gap,' above mentioned, between the odor consciousness and the tone consciousness.

The results for *S* and *Wh* are likewise correlated directly with what the introspection had indicated as the effects of distraction. Both of these observers felt keenly the loss of the image (*Wh* of the auditory image, *S* of the auditory image and of the opportunity to identify *N* visually and otherwise), and it is reasonable to suppose that its loss minimized the expectation error, for if there is not in consciousness a certain definite place which *V* is expected to reach, there is an absence of material for expectation.<sup>2</sup> This factor is, now, supplemented by the influence of the 'gap,' which is of longer duration for *S* and *Wh* than for *B*. Finally, *S* and *Wh*, in their confusion at the loss of the standard, turn to *V* for some indication of familiarity, and are apt to wait too long in this effort to gain

<sup>1</sup> The reduction was, on the whole, more apparent with a descending variable (just why cannot be stated), so that the estimation value of *N* has changed its sign with the smallest and the largest *D*. But this change is insignificant; the values have actually changed but little, and are, all of them, less than one vibration in amount.

<sup>2</sup> It may be objected that *B* ought, on this line of argument, to show no expectation error. But *B* adopted her method of decision quite naturally, whereas *S* and *Wh* in the present series are thrown upon this method which is foreign to their natural procedure. Moreover *B*, as we have explained at some length, is influenced by an habitual-time factor which produces an expectation error.

"some clue to N." Whether these three are the essential or the sole factors involved, the fact that the expectation error is very materially broken up is very patent from the Table. Note especially the reversal of the sign of the error in five out of six cases for *S*, and half the cases for *Wh*, and, more striking yet, the complete reversal of the rule that the average limit of error increases as *D* increases.

*M*, as might again be predicted from the introspection, occupies an intermediate position between *B* on the one hand and *S* and *Wh* on the other. There is a single change of sign and the progression of the average limit of error is partially destroyed.

### RÉSUMÉ OF PART III.

In Part III we have continued our examination of the problem set forth in the title, giving special attention, however, to the second phase of the question, *i. e.*, to the structural analysis of the consciousness present in the functions of discrimination and recognition.

All the experiments of Part III were made by what we may term the method of reaction or the method of continuous change; its essential feature was the use of a continuously sounding variable which moved from above or from below the standard toward this standard at a uniform rate until arrested by the observer at subjective equality. Four series were conducted: Series 1, ten seconds time-interval, image held; Series 2, 40 seconds interval, image held; Series 3, ten seconds interval, procedure with knowledge, image held; Series 4, ten seconds interval, image lapsing with the aid of artificial distraction.

The quantitative results of these four series are best gleaned from Tables VII to X.

The qualitative results (largely gained from the introspection) are given below in general outline. It should be understood that, owing to the extremely individual character of the treatment of the results (a character which it has been the aim of this thesis to exploit), such a summary is at best merely a very rough outline of the more striking facts which are common to most of the observers. The individual variations which have been discussed at length in the text are, in our opinion, psychologically even more important than any number of generalizations.

(1) Some observers are able to classify and identify the standards in use by auditory-verbal, visual and other associative supplementing. This process is apparently helpful in the reaction.

(2) The variable tone seems to move toward N by stages

which may be regular or irregular. The movement is frequently visualized, and observers have distinct emotional preferences, some for an ascending, some for a descending, tone. The direction of movement is frequently misinterpreted, and illusory movements appear even during the procedure with knowledge.

(3) The method and basis of the decision is distinctly an individual matter; we may, however, distinguish certain types. The attention may be directed (1) upon the image, (2) upon the variable, or (3) alternately upon the image and the variable. (1) When the attention is upon the image, the decision results from the appearance in the variable of a tone (or visual substitute) which 'matches' the image. (2) When the attention is upon the variable, the decision results (a) from the appearance of some tone or 'place' in the variable which resembles the standard (whether the image is recalled or not), (b) from some subjective change in the intensity, timbre or movement of the variable, or (c) from some change felt in the observer's body which is indicative of familiarity. (3) Attention of the alternating type, in so far as it involves a series of auditory comparisons between the image and the variable, is present only in the early tests before the observers attain practice: a form of alternating attention not involving comparison (a single shift from the image to the variable when near equality) is also used by some observers occasionally. Still other decisions are the result of an inference, based upon the size of  $D$ , as to the time required to reach equality. Finally, some decisions are not recognitions at all, but mere guesses set off without regard to the actual tonal relations.

(4) The movement of reaction (finger-key) becomes automatic for all observers, though much sooner for some than for others.

(5) After the reaction there is heard a distinct additional movement of the variable which we have termed the 'after-tone;' some observers make use of this to evaluate their reactions.

(6) There is a strong tendency to react too soon; in other words, an error of expectation. This is fostered by several contributory factors, but partially counteracted with varying success by conscious attempts at restraint.

(7) Expectation increases as  $D$  increases, save for some observers when under distraction.

(8) No observer can say definitely that a given reaction is exactly correct. Reactions possess merely a varying degree of satisfaction. There is an area, rather than a point, of equality.

(9) Procedure with knowledge of the position of the coming

variable has little effect upon the quantitative results. It merely gives a sense of security to those observers who had occasional difficulty in apprehending at once the position of the variable. On the other hand, there is a tendency to be obsessed by an anticipatory image of the variable,—a tendency which may be a source of some disturbance.

(10) The long time-interval produces irregular quantitative results, owing largely to its deleterious effect upon the image.

It is helpful to have the image persist in some form through the interval, so that the amount of D at least may be used as a basis for the reaction; but it is possible to make objectively satisfactory reactions when the image has been permanently lost before the sounding of the variable. Such decisions are usually based upon 'familiarity feels,' and are subjectively quite unsatisfactory to observers accustomed to the use of the image. Difficulties in the apprehension of the position and movement of the variable, which are increased by the long time-interval, confirm a previous assertion that there is a tendency to sharp the image with long times.

(11) Distraction by odors is successful in the majority of instances, though observers using the image in the decision are more apt, with the continuous change method, to have the image in consciousness during the decision. Distraction interferes with the process of identifying the standard, and renders the apprehension of the position of the variable more difficult; there is a distinct gap between the odor consciousness and the tone consciousness. Complete distraction compels all observers to attend to the variable and to react without reference to an image. All observers have less assurance. Those addicted to the use of the image no longer exhibit an expectation error.

(12) Practice lessens the mean variation, and unifies the course of the reaction consciousness of each observer, though, at the same time, individual differences are accentuated.

(13) The method of reaction, since it calls, so to speak, for a 'quantitative' as well as a 'qualitative' discrimination, leads to certain results quite different from those of the tests with discrete tones. Most important is the fact that observers who excelled in the discrimination of discrete tones without the use of the auditory image find the reaction to auditory equality is most satisfactorily accomplished by the keenest attention to the standard and the use of the auditory image as a basis for the reaction.

## PART IV.

*Miscellaneous tests.*

The miscellaneous tests of Part IV deal with points raised during the previous experiments, especially those with discrete stimuli in Parts I and II. Of these tests, those involving the associations of color to tones have already been discussed.<sup>1</sup> There remain to be mentioned the pneumographic tests, the drawings of the movement of continuous tones and the chronometric measurements of the judgment-time.

The *tracings of respiration*, obtained under various conditions by means of a Verdin pneumograph and a continuous-paper kymograph driven noiselessly by a distant water-motor, failed to establish any very instructive correlations. The one obvious result worthy of mention was that shallow and irregular breathing ensued whenever the attention was sharply concentrated,<sup>2</sup> as, for example, in the endeavor to bring back an image clearly just before V, or, better yet, in the reaction-consciousness, where, as we have already pointed out, there was nearly always visible excitement and a high degree of expectant attention.

The *drawings of the movement of the variable tone* used in the continuous-change method were made partly to elucidate the general nature of the subjective movement of the variable, but in particular to see how far the visualizations reported by observer S could be objectively recorded. At first, in accordance with the suggestion of Stern,<sup>3</sup> we tried to register these movements by means of the kymograph above mentioned. The observer rested her wrist upon a smooth metal rod fastened horizontally parallel to the plane of the paper. A cardboard screen, in which was cut a narrow slit the length of the width of the paper, was then attached to the apparatus just above the paper: the object of this screen was to allow the observer to trace the movement of the tone with a pen, the point of which was free to move to the right or left along the slit, while at the same time, the tracing was covered up as fast as it was made. A time-marker gave the requisite control. The tests then proceeded in the following manner. When N sounded, S touched the paper for a moment to indicate the place (visually and spatially) of the standard; when V sounded, S again placed the pen up.

<sup>1</sup> First article, 420; also this *Journal*, X, 1900, 318.

<sup>2</sup> Cf. the results lately attained by P. Zoneff and E. Meumann (*Phil. Stud.*, XVIII, 1901, 1-113) who say (p. 44) "Alle diese Angaben . . . führen zu der Annahme, dass eine willkürliche Concentration der Aufmerksamkeit eine Verlangsamung des Pulses und eine Hemmung der Athmung bewirkt."

<sup>3</sup> *Veränderungsauffassung*, 117.

on the moving paper at the right or left, for a 'plus' or 'minus' D respectively, and then moved her hand in toward the center of the strip just as V seemed to her to move, taking the pen off when she thought V reached the position (auditorily and visually) taken by N. This method of procedure was at first reported to be quite natural and easy, though the movement from right to left was less natural than the opposite one. As the experiments continued, however, objections appeared. To begin with, there was so much for the observer to think about, the starting of the machine, execution of the drawing, making the reaction, etc., that procedure without knowledge of the position of the coming V (always more difficult for S) had to be given up. Finally S was never satisfied with the resulting curves; the ordinates were not commensurate with the actually experienced tonal 'slumps,' so that the curves represented little but the number and frequency of the 'steps' taken by the tone. Accordingly, at the observer's suggestion, the moving paper device was given up. In its place the following method was adopted. With closed eyes, S indicated the place of N, and the starting point and entire movement of V, upon a stationary sheet of paper. The results were entirely adequate representations of the spatial behavior of the tones.

It is rather difficult to describe these drawings briefly. To begin with, N is almost always identified as one of a series of standards, this series consisting of six or seven round, grayish spots. The whole series is not seen at once, but merely the two or three spots in the region of N.<sup>1</sup> But the actual N is not only identified as one of these gray spots; it is always manifested as a horizontal line about three-fourths of an inch long, moving from left to right. The variable starts at a point in space about four inches to the right<sup>2</sup> and four or five inches above or below the place of the standard. When above, it descends vertically, but when below, it rises obliquely to the left. In either case, the movement is such that the gray ball representing V executes a series of curves with the result that, on the side toward S, *i. e.*, on the left (naturally the only visible) side, a gray rope is formed, whose outline is an index of the number and nature of the slurs in the movement of V. The actual number is a very uniform function of the time consumed by the tone; each slur representing two seconds, *e. g.*, when D = 14.0 vibs. (ten seconds necessary to reach equality) five slurs would be drawn. Finally it was found, much to the surprise of S, that the stop-

<sup>1</sup> We have noted that S thought, at first, that there were six or seven, later, three or four standards. Apparently, she finally came to classify correctly into a high, medium and low *region*, only she thought that each region contained several tones.

<sup>2</sup> This distance is more or less arbitrary; occasionally it is shorter.

ping point of the tracing of V (subjective equality) was almost invariably exactly opposite the point at which N had been placed, this giving a most striking confirmation of the vividness and distinctness of the visualizations, and of the readiness with which they might serve in the determination of the reaction.

*The recognition-time in immediate judgments.* In Parts I and II it was clearly demonstrated that, under the conditions of our experiments (8 vibs. D, with three possible judgments, etc.), the variable stimulus could be recognized as the same as, or as higher or lower than, the standard, in a very brief time after the sounding of the variable; this though the time-interval were 2 or 60 seconds. The introspection bore out this observation, for it was evident that these judgments were made without any process of comparison between the variable stimulus and the image of the standard; they could be made when all trace of the image was removed by suitable distraction during the interval. We termed these judgments *immediate*, meaning that no comparison was present, whether or not there was at the moment any trace of the auditory image in consciousness. That, within the judgments thus classed as immediate, there might be differences in the actual rapidity of the decision has been definitely stated.<sup>1</sup> It now remains to be seen whether these judgments are actually as rapid as the introspective reports indicate, and whether they are fast enough to warrant the conclusion that it would be impossible to have in the consciousness under measurement any process, however fleeting, involving reference to the image.

In order to investigate these points, the following arrangements were made. The air-cock of the blown bottle apparatus was equipped with metal contacts such that a circuit passing by way of a lip-key to a Hipp chronoscope was completed as soon as the air-cock was opened far enough to produce an audible tone from the bottle.<sup>2</sup> Observers *M*, *B* and *Wh* were then practiced in the use of the lip-key and the, at first rather difficult, task of expressing their judgments audibly. Advantage was taken incidentally to secure what we may call the 'speaking-times,' *i. e.*, the time necessary to pronounce the

<sup>1</sup> For example, first article, 443, 3.

<sup>2</sup> It is to be noted that this arrangement is open to a slight error, for, in actual operation, the air-cock is opened suddenly to its full extent so that contact must be made slightly before the current of air has rushed through the four feet or so of tube and set the bottle in action. This, error, however, is very slight, and the form of apparatus used was the most feasible of several that were tried. Moreover, the error, whatever its size may be, lengthens the reaction-time, and hence cannot be construed as contributing to the advantage of the results sought.

judgment words, 'higher,' 'lower,' 'same,' etc.,<sup>1</sup> in response to a single isolated tone, the actual conditions of the experiment thus being in play, with the exception that no standard was given, and that the time measured was, therefore, a single perception-time instead of a recognition-time.

The figures in Table XI represent introspectively valid tests only, those in which the judgments are rated by the observer as correct and immediate. From this Table we wish to make simply the following points, both of which are in complete accord with the introspective evidence already given.

TABLE XI.\*  
(*Recognition-Times. All results in sigma.*)

Obs.	Cases	D = +8	m. v.	D = 0	m. v.	D = -8	m. v.
<i>M</i>	4	657	46	849	37	787	47
	6	407	48	402	49	341	42
<i>B</i>	4	464	99	659	70	609	56
	5	312	63	315	56	384	96
<i>Wh</i>	8	754	101	815	87	709	55
	6	317	36	350	27	294	21

\* For each observer the first line represents the recognition-times, the second line the simple reaction.

(1) The recognition of tonal equality or specific difference can be given verbally in about three-quarters of a second. Hence, under the conditions of our tests, judgment is complete before the variable ceases to sound.

(2) Difference and its direction are more quickly recognized than equality.

One is tempted to carry the interpretation of the results still farther, to show, *e. g.*, that the relative speed of judgments of higher and lower in the case of *B* is in accord with her introspective verdict that 'higher' is the easiest and quickest judgment, and that it is to be related to the tendency to pass that judgment.<sup>2</sup> But the cases are very few in number and the mean variations are large. Even after the preliminary practice it was rather curiously difficult to secure a satisfactory series; a half-dozen tests were sometimes necessary to secure a

<sup>1</sup>The observers had strong preferences for the particular word which they used for the judgment, so that it was thought best not to insist upon uniformity in this respect: accordingly *M* used 'higher,' 'equal,' 'lower,' *B* 'high,' 'sa-' (for same), 'low,' while *Wh* used 'higher,' 'equal,' 'lower.'

<sup>2</sup>First article, 450.

single entirely valid result.<sup>1</sup> Of interest, finally, are the times of a few incidental judgments in which the observer was uncertain. The correlation of uncertainty with slow rates is clearly shown for in all these instances the times are over one second.

The chronometric tests, then, give objective verification to our assertion that immediate judgments are made so rapidly as to exclude the possibility of the process of image-comparison.

### CHAPTER III.

#### CONCLUSIONS AND THEORETICAL IMPLICATIONS.

To gather together all the principal results of our investigation into brief compass, and, at the same time, to allow each item its proper significance is quite out of the question. Most of the results were obtained under specific conditions, and should not be stated baldly without reference to those conditions. The reader is accordingly referred to those portions of our text in which summaries and conclusions have already been given: most important are,—for the quantitative results, first article, 421, 422, present article, 223-4, 243-4, 250-1; for the qualitative results, first article, 443-6, 448, 455-6, present article, 230, 239, 252-4.

While we keep these specific conclusions in mind, we may venture, however, to discuss the outcome of our investigation, taken as a whole, upon the two problems set forth in the introduction,—the nature of the memory image for tones, and the nature of the consciousness involved in the judgment or decision.

#### THE NATURE AND COURSE OF THE IMAGE.

In regard to the nature and course of the memory image of both clangs and tones, we may conclude that:

(1) The auditory image is but one part of a complex structure which represents the original experience. Put briefly: the memory image of a tone is not a tonal memory image; it is that and much more. A tone is held in memory not only as an auditory quality, but also as a definite quality, possessing marks which help to identify it. These marks of identifica-

<sup>1</sup> Some of the difficulties are indicated by the following quotations: "Possibly opened lips too soon." "Said 'same' instead of 'equal.'" "Hesitated slightly for word." "Completely rattled: too anxious to make a quick decision." "Opened lips before I said the word." "Tendency to say 'equal,' then said 'higher.'" "Slow judgment." "Not sure of judgment." "'Equal' judgments naturally need the verbal expression to 'cap' them, but 'higher' and 'lower' I know before I can speak the word. Not natural for me to put the verbal sign on till later."

tion are supplementary contributions from various modalities,—visual, temperature and strain sensations, associations of various sorts, affective reactions, etc. The relative importance of these various features varies with the individual observer, and the conditions under which he is placed.

(2) The auditory image proper, usually of the timbre of the stimulus and localized at the instrument, attains its maximal excellence about two seconds after the stimulus; thence, despite the active use of memorial aids such as visualization, contraction of throat muscles, etc., it gradually wanes, suffering most in intensity, less in clearness, least in quality. It is in a very unsatisfactory condition at 40 seconds, and often entirely gone at 60 seconds.

(3) The image apparently *tends* to flat, but this tendency is more or less consciously resisted by most observers, so that, at least at 30 seconds or afterwards, it is more often sharp.

(4) The other constituents of the memory image do not necessarily follow the course of the auditory core; they may be serviceable for purposes of discrimination when the auditory image has disappeared entirely. This independence of the supplementary features of the memory image complex is best shown in the course of the memory image during long time-intervals. We have frequently mentioned the disappearance of the auditory core or its arbitrary alteration under these conditions.

(5) Continued practice with a stimulus of a particular clang color (tonometer or bottle) increases the serviceability of the image: it becomes more intense, clearer and of longer duration.

(6) The task of actively holding the image very soon develops a habit of imaging; the image, that is, of itself becomes insistent, and so insistent that, when exclusion of the image is desired, very active attention to naturally powerful distractors is necessary completely to repress it for relatively short intervals (10 seconds). Yet the ease with which distractors overpower the image is largely dependent upon the mental constitution of the individual: observers who make little use of the auditory image in the decision, observers who are not auditory-minded, and observers naturally attracted to odors, are able to repress the image with relative ease.

#### THE PROCESS OF JUDGMENT.

In turning to our second problem, the analysis of the judgment consciousness, let us note (1) that the method of right and wrong cases which we employed in the earlier tests really yields results obtained under two quite dissimilar conditions, viz.: (a) when  $D = 0$ , and (b) when  $D = \pm 8$ . However the quantitative results are treated, one must differentiate qualita-

tively between judgments of identity and judgments of difference, and, again, between simple judgments of difference without direction, and definite judgments of a difference and its direction.<sup>1</sup>

We must further note (2) that the values yielded by the reaction method, on account of the peculiar conditions which we have attempted to analyze, cannot be compared off-hand with those obtained by right and wrong cases. We cannot even say that the determination of subjective equality in the former method is akin to the judgment of equality in the latter. Yet, despite these radical differences, both methods furnish us with data which admit of unification in generalizations as to the mechanism of judgment.<sup>2</sup>

The following conclusions summarize the evidence we have obtained in regard to the structure of the judgment consciousness.

(1) The presence of the auditory image is not necessary to the recognition of either difference or equality. Judgments without the slightest trace of comparison were so frequent as to be the prevailing type for most observers. Their existence is attested by the introspection of the observers, by the tests made under distraction and by the chronometric measurement of recognition-times.

(2) The auditory image may be present in the judgment consciousness, but not itself an object of attention, not serving as a basis for comparison.

(a) This is most common in judgments of identity, when, although the recognition is immediate, the variable tone seems to re-enforce, or flow into, the image. Two interesting questions arise here: is the presence of such an image useful? Again, is it possible that its absence is the cause of the rapid

<sup>1</sup> It is clear that this division disregards the distinction between right and wrong cases: judgments of difference might be given with objective equality, etc. But the errors have already been discussed; for present purposes our immediate object is to deal with the right cases only.

<sup>2</sup> It may possibly be objected that the term 'judgment' cannot properly be applied to the reactions of the continuous change method or to the flash-like immediate answers in the case of discrete tones, on account of their simplicity and semi-automatic nature. J. Royce (*Psych. Rev.*, IX, 1902) seems to imply that Marbe's experiments (*Experimentell-psychologische Untersuchungen über das Urteil*, Leipzig, 1901) are open to this objection, for, after stating that Marbe undertook to investigate the psychology of the judgment, he says (115): "therefore it was the experimenter and not the subject in whom the process that was to be studied went on." We must, however, remember that mind is full of short cuts, that mental processes follow psychological courses rather than logical patterns. The experimentalist must work at first upon the analysis of comparatively simple bits of content; cf. our recommendation below, p. 268.

decline of right cases for  $D = 0$ , as time-interval increases? The fact of this decline is clearly established: it was found by Angell and Harwood and by Wolfe. That long time-intervals seriously affect the auditory image is equally definitely made out. Let us, then, consider this question first.

One must bear in mind that long time-intervals affect the image in several different ways; its pitch, its clearness and its intensity, all are influenced. Now, though we have just stated that the image suffers least in pitch, it is, nevertheless, evident that a slight change just here would be most disastrous to the successful execution of *qualitative* discrimination. We have, as a matter of fact, been several times forced to take cognizance of the tendency to sharp the image, and we have shown definitely<sup>1</sup> that this tendency, as manifested by the error of judging — instead of — (and possibly, also, that of — instead of +, though the conditions are there rather different), is markedly increased by long time-intervals. In other words, the effect of time-interval upon right cases is largely due to the sharpening of the memory image (including both auditory and supplementary components) rather than to its absence. Further discussion of this point would, therefore, lead us into the matter of judgments of higher and lower, and this we must defer to a later point.

The first question still remains:—is the auditory image which is merely present and not the object of attention, at all useful in those judgments of equality which are *correct*? We are of the opinion that, on account of its not being a direct object of attention, the image in these cases forms simply one feature in the 'familiarity feel,' which, as we shall try to show in a moment, is, in part, characterized by the ready provocation of centrally excited sensations. If the particular pitch which is recognized happens, when V sounds, to be actually in process of central excitation in the form of an auditory image of the standard, then the recognition is, in all probability, aided by this fact. The ease of the reception of the variable stimulus is distinctly enhanced, and the variable is then, for the observer, recognized as the *same tone* as N, rather than as merely familiar.

(b) In judgments of difference, likewise, the image may be present when the variable sounds, but it is then almost invariably thrust out of consciousness by the direction of the attention to the variable, and the judgment is determined for the most part by other factors. The advantage of the persistence of the image into the beginning only of the variable, in the reaction method, constitutes a special case. The image is not then present in the judgment proper; it is merely an accessory

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<sup>1</sup> First article, 422, 2 (b).

to a preliminary judgment of the position of the variable at the start. Here it seems to aid some observers who react in terms of elapsed time, to make a more definite notion of the amount of D.

(3) The auditory image may be an essential component of the judgment consciousness, becoming a direct object of the attention, after the attention has once been given to the variable. Such judgments exhibit a true process of comparison.

(a) When working with discrete tones, judgments by comparison appear in cases of difficulty, when the conditions are novel, when the variable fails to touch off the decision at once, when two contradictory impulses are felt. In short, the deliberate use of the image as a standard of comparison is a more complicated device, a round-about path, indicative of obstacles, uncertainty and hesitancy. Its results, moreover, are themselves uncertain and quite as likely to be wrong as right.

(b) When working with continuously changing tones, the auditory image may be, even for observers who entirely neglected it with discrete tones, the object of constant attention, the standard to which the variable is compared,—whether by a series of rapid alternations of attention, or by active attention to the image (the variable itself being, since peripherally excited, sufficiently insistent without attention). This apparent change in the function of the image is but apparent. The conditions of the reaction method demand an exact identification of the variable and the standard, not a simple choice of one out of two or three possible answers. We have frequently shown that the reaction was felt to be merely an approximation, and that there was never absolute certainty. Now all this is tantamount to saying that the reaction calls for a very careful discrimination. This is more difficult, and hence it is not surprising that some observers make the fullest use of the memorial representation of the standard.

We have already mentioned, also, that, in many cases, the auditory image received attention up to the time the variable sounded in order to get a more exact determination of the amount of D, and hence to furnish indirectly a basis for the execution of a reaction at the expiration of a definite time-period.

We must now consider cases (1) and (2), especially the former, more fully, and seek to show what replaces the auditory image as the basis of judgment. Two main types must be explained, viz.: positive judgments of 'higher' and 'lower,' and judgments of identity. We may then discuss, finally, judgments of difference only, which may or may not involve the image.

4. Judgments of 'higher' and 'lower,' made without conscious reference to the image, are largely analyzable into com-

plexes of strain sensations, with less prominent visual and organic elements, set free neurologically by the variable stimulus. The two chief factors, feelings of tightening and relaxation for 'higher' and 'lower' respectively, were reported throughout the tests with discrete tones, and were also well brought out with the wide differences used in the reaction method. We believe that these strains, which are especially noticeable in the chest, throat, eyebrows, scalp, and about the ears, are explicable as symbols for 'upness' and 'downness' in the tonal continuum, set up by every-day experience, especially in executing and listening to music. Of course, it is impossible actually to differentiate innervations of the vocal cords within the small limits of tonal differences employed (the maximum D with discrete tones being less than  $\frac{1}{8}$  of a whole tone), yet the variable stimulus may arouse a complex of sensations,—partly centrally, partly peripherally excited,—which means simply 'high' or 'low.'

For certain observers who are extremely visually minded, the visual features set up by the stimuli may play a more important part than the strain sensations. The actual muscles concerned in mediating the strain sensations are also quite different for the different observers, but the general fact exemplified throughout is that judgments of 'higher' and 'lower' are usually mediated by the associated or supplementary components of the consciousness set up by the variable. Strain sensations seem to be, *par excellence*, the symbols of rise and fall in the tonal continuum.

The reasonableness of this explanation is, we think, attested very definitely by occasional instances in which imagery more specifically associated with the tonal scale was the deciding element in the judgment. The instances referred to are visualizations of a printed musical scale, of a piano key-board, the kinaesthetic imagery of striking one piano note a half tone above another, etc.

(5) Judgments of equality or identity without the presence and use of the auditory image are, as we have said, not so frequent as judgments of difference. When working with discrete tones, V is apt to bring up the image of N, though equality may be immediately recognized without comparison. We have intimated that in these cases the image simply became one part of the familiarity feel. We have now to consider more fully the nature of this feel, and to take into account, especially, judgments of equality in which the auditory image is entirely absent, (e. g., with long intervals and distraction in the case of discrete tones, and with both these and the cases of observers who attend to V, in the reaction method).

Both of these types of judgment present clearly the problem of the *familiarity feel*, since in both types, there is absence of

any image and of the process of comparison. What is the structure, then, of the familiarity feel? Most pertinent in this connection are the continuous change experiments, for every reaction is an indication of equality. Discarding all tests in which an image of N was present, we find that the remainder may be placed in two groups, according as to whether familiarity was based (*a*) upon some subjective indication in the variable tone itself, or (*b*) upon some general indication afforded by the observer's own body.

The indications of the first type are exemplified by the following phrases culled from the introspection: the variable at equality is said to be,—graspable, appealing, more noticeable, louder, stronger, lingering along, standing out, a warmer gray, rounded-up visually, splayed out, etc. It is evident that many of these modifications of the variable refer to other than auditory features; thus, the first is *tactual*, the last four obviously *visual*. We are again reminded of the prominence of the associated and supplementary components of the auditory experience which were in evidence in judgments of 'higher' and 'lower.' It may be supposed, then, that the standard arouses a more or less definite complex of sensations, and that when the variable stimulus arouses the same, or a closely similar, content, the identification is affected. In other words, that point of the variable stimulus is familiar which has a peculiar effectiveness for the arousal of centrally excited sensations.<sup>1</sup> Such phrases as 'appealing' and 'my tone' indicate very obviously that the identified tonal quality is, if one may use the term, peculiarly 'apperceivable.'

The indications in the second type are much less varied in nature and much less frequent in occurrence. Typical experiences are given in the phrases:—"glow of warmth," "kind of jumped all over," "felt a sense of ownership." These experiences seem always tinged with more or less pleasantness. They remind us of the pleasant "mood of feeling at home" which has often been attributed to the *recognitory consciousness*.<sup>2</sup> It is to

<sup>1</sup>Cf. Külpe, *Outlines of Psych.* New York, 1895, 172; Titchener, *An Outline of Psych.*, New York, 1899, 274.

<sup>2</sup>E. g., Külpe, *op. cit.*, 172 ff; Titchener, *op. cit.*, 274 ff. The term 'mood' is, we think, rather objectionable as it connotes, to use the latter author's terms (241), "the weaker emotive states which persist for some time together." The affective reaction present in our recognitions may be very short-lived. On the other hand the term 'mood' has the distinct advantage of indicating the origin of the feeling of familiarity, since it refers us to an emotion as the primary source, and thus gives a biological explanation for the experience. There should be something in our terminology to indicate the distinction between such 'weakened' and 'degenerated' feelings and other feelings which are not the products of this line of development. Possibly the term 'secondary feelings,' on the analogy of the secondary reflexes, might serve to distinguish

be noted that, in common with the familiarity marks of the first type, these indications are components of the associative fringe which gathers about the auditory core and serves to give it individuality and identity. On the other hand, these components must be different in origin. The changes felt in the tone serve to identify that particular experience. But the general bodily reaction stands for familiarity in general; the variable is not the-same-as-N, but simply familiar. Such a reaction might identify as familiar, experiences quite other than those with which we have been concerned. Indeed, one would be very much more likely to experience the 'glow' of familiarity in situations in which the content of the experience had more complexity, more interest and vital importance than can be instilled into laboratory tests in the recognition of pitches.

Finally, recognitions of familiarity were not, at times, analyzable to the extent just described. The first thing to appear may be merely some auditory-verbal reaction,—perhaps the words 'equal' or 'same,' or, in the reaction method, the phrases 'that's it,' 'now's the time,' etc. In these cases we think the explanation is simple. The relatively complex content which marks more definite identification is replaced by merely the word content, 'known.' In all probability, even such recognitions are not made indifferently. We may suppose that the feeling of 'at-homeness' is also weakly present. The conditions of experimentation, however, lead the observer's attention to the verbal formulation, and the other features escape notice in that particular judgment. We have already called attention to the one-sidedness of individual bits of introspection. If we admit, then, that the cases under consideration exhibit both the auditory-verbal 'known' and a weak feeling of ease, we have shown enough to explain the execution of the judgment. A good analogy, which shows how the auditory-verbal consciousness may represent what was once more complex, is to be found in the development of cutaneous local signature, where the marks of locality, once, in every probability, made up of a complex of pressure-strain-articular-muscular sensations, became visual, and, ultimately, auditory-verbal.

Now the familiarity mark is quite as difficult of analysis as the locality mark, so that when we have procured, as in the present study, several thousand introspective analyses, we are warranted in assuming that the evidence of the majority of the cases, taken together, is most illuminative, and that, in the light of this evidence, those cases in which introspection fails to discover all the customary marks of familiarity, and, too,

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these from the others which might then be termed the 'primary feelings.'

those cases in which introspection fails to reveal any trace of the mechanism whatever (*i. e.*, in which the tones is simply familiar, and that is all), that these cases are not to be mistaken as evidence for the unanalyzability of the familiarity feel, but rather of the limitations of the particular bits of introspection involved. We are not compelled to assume an unanalyzable 'quality of knownness' (Höffding), or an irreducible attribute of centrally excited sensations (Washburn).

(6) Judgments of difference in which the direction of the difference is unknown are quite common for some observers. They rarely appear except when there is an actual objective difference.

To explain them it must first be noted that they are of different types. We may distinguish at least three.

(a) Those involving the process of comparison and the use of the auditory image. This type is found in the case of observers who make most use of comparison (*e. g.*, *W*). The attention alternates several times between the two images,—that of *N* and that of *V*,—until the identity of the two becomes confused, so that the observer knows that one is higher, but cannot tell whether it is the image of *N* or of *V*.

(b) Those in which there is no comparison and no use of the image. Judgment results from a 'motor' or visual 'shift' set up by *V*, only this reaction is not definite like that symbolic of 'high' or 'low,' it simply indicates a change or difference. The possibility that a stimulus can reproduce the judgment of difference without producing a more definite judgment of the direction of the difference has been frequently stated. The explanation given by Külpe<sup>1</sup> and by Stern<sup>2</sup> seems quite adequate in the present connection. Finally, we may distinguish a third type.

(c) Those in which judgment does not stop at the assertion of difference as in (b), but in which the direction of the difference is afterwards successfully ascertained by voluntarily "hauling up" the image of *N* and performing the process of comparison.

This completes our problem. We have endeavored to present an exhaustive analytical investigation, with the aid of two distinct experimental methods, of the mental processes involved in the discrimination of simple tones and clangs as conditioned by time-interval and by the mental constitution of the observer. We have endeavored finally to express in as compact a manner as possible the generalizations of the facts

<sup>1</sup> *Op. cit.*, 173 f.

<sup>2</sup> *Veränderungsauffassung*, 251.

adduced and the theoretical significance of these generalizations.

Certain problems have appeared in the course of the investigation which might well receive further discussion and further investigation. We have, for example, been impressed with the prominence of the spatial characteristics of tones. While we cannot here amplify the proposition, we may assert that, in the light of our introspective evidence, there is nothing innately or innately spatial about tones; that all their spatial characteristics are secondary and supplementary, the product of experience with very special emphasis upon the spatial characteristics of the source of the sound.

Another problem which would be suitable for experimental investigation, and closely related to our own subject is to be found in the recognition and discrimination of auditory qualities whose pitch (at least that of the standard) is not that of a single isolated note, but that of a cadence or melody, or of a chord. Such a content would present conditions more nearly resembling those of actual life. The mechanism of recognition might conceivably be more complex, but at the same time more open to view. The influence of absolute pitch, of musical training, of the nature of the imagery, would all be more apparent than in the case of isolated tones. From the writer's own experience it seems probable, also, that such tests might be made with time-intervals greater than those here employed.<sup>1</sup> The point of attack must be throughout qualitative (though fidelity of memory, or, to speak more strictly, capacity of recognition, might be incidentally determined), and great attention must be paid to the peculiarities of individual observers.

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<sup>1</sup> Cf. Stern, *Veränderungsauffassung*, 206, "Für einen einzelnen Ton ist die Reproduzierbarkeit zeitlich eine viel beschränktere, als für den Klang einer Stimme oder für eine Melodie."





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